NAVAL ELECTRICIANS' TEXT BOOK

Volume II

PRACTICAL

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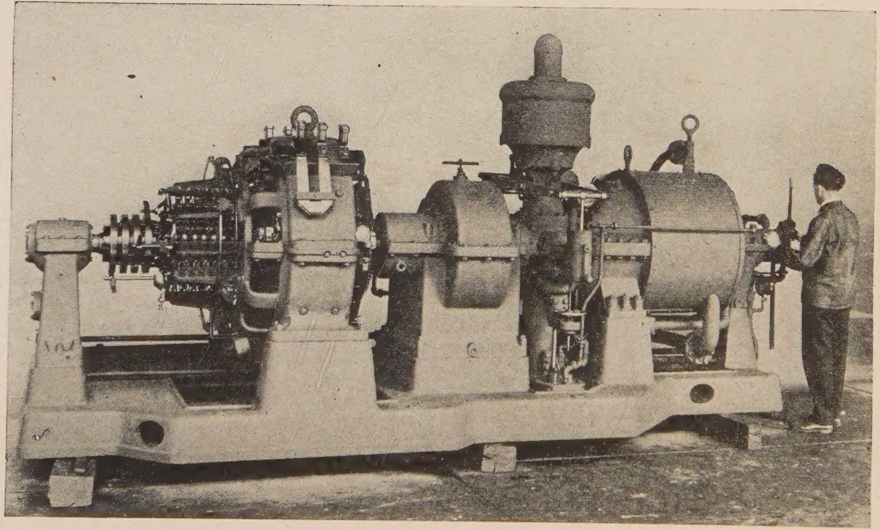
PRACTICAL



300 KW., THREE-WIRE GENERATOR, WESTINGHOUSE ELEC. AND MFG. CO.

NAVAL ELECTRICIANS' TEXT BOOK

Volume II

PRACTICAL

BY

Captain W. H. G. BULLARD, U. S. N.

REVISED BY

DEPARTMENT OF ELECTRICAL ENGINEERING AND PHYSICS

U. S. NAVAL ACADEMY

FOURTH EDITION

1917

United States Naval Institute

Annapolis, Maryland

NAVAL ELECTRICIANS' TEXT BOOK
VOL. II
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PREFACE

This book is a revised and enlarged edition of the Naval Electricians' Text and Hand Book. Many new chapters have been added to the original manuscript and all have been more or less rewritten and to such an extent that it has lost its hand-book characteristics. As stated in the first edition, there is probably little or nothing contained in it that cannot be found elsewhere, but an attempt has been made to collect complete information concerning the principles and uses of electricity as applied to our ships of war.

It is primarily intended for use as a text book by midshipmen at the Naval Academy, but officers and the enlisted personnel and electricians should find it a fairly complete treatise on electricity as far as it relates to the subject of our warship installation.

It would be difficult to give credit to all those who have made suggestions for improvement of the book, but special mention should be made of the officials of the General Electric Company who have contributed many illustrations of the appliances made by them and furnished much valuable manuscript. Due credit has been given to other manufacturers and to those who have allowed the results of their experiments to be used.

W. H. G. Bullard,
Lieut. Commander U. S. Navy.

PREFACE TO SECOND EDITION

The first edition of the Naval Electricians' Text Book was published in one volume. In an endeavor to bring the subject matter up to date and to keep pace with the constantly increasing installation of electrical material and apparatus in our ships of war, as well as to make it a complete text book covering all electrical principles concerned, the manuscript has grown beyond the proper proportions for a single volume. The present edition has accordingly been made up in two volumes, in one of which the purely theoretical matter has been placed, and in the other, descriptive matter of material, apparatus, methods of control, etc. The division is somewhat arbitrary, but the aim has been to keep the theoretical matter separated from the practical as far as possible.

Much new matter has been added, and while it is impossible to furnish descriptions of every piece of electrical apparatus that is installed on our ships of war, enough typical equipments have been described to illustrate the general subject and to show the electrical principles involved.

The compiler wishes to take this opportunity to express his appreciation of suggestions by many officers of the service, and particularly the assistants in the Department of Electrical Engineering, leading to changes and improvement in the manuscript, and of the courtesies extended to him by manufacturers of electrical apparatus, particularly the officials of the General Electric Company, the Cutler-Hammer Electric Manufacturing Company, the Diehl Electric Manufacturing Company, the Walker Electric Company, the Holtzer Cabot Electric Company, the Cutter Electrical Company, the Sangamo Electric Company, the Reliance Electric Engineering Company and Chas. Cory & Son, all of whom have freely furnished much valuable information and data.

W. H. G. Bullard,
Commander U. S. Navy.

July 1, 1911.

PREFACE TO THIRD EDITION

VOLUME II

The second edition of the Naval Electricians' Text Book having been exhausted, it was desired to revise the book before issuing another edition. Captain W. H. G. Bullard, U. S. N., the author, was unable to undertake this revision for the reason that his important duties as Superintendent U. S. Naval Radio Service required his undivided attention.

In this connection it was decided to completely revise the first volume, but, due to the limited time available, to reprint the second volume with notes and corrections and an appendix containing a description of some of the later applications of electricity for naval purposes.

The information contained in the appendix was compiled chiefly from data kindly supplied by the Bureau of Navigation, the Bureau of Steam Engineering, the Bureau of Construction and Repair, The Cutler-Hammer Electric Manufacturing Company, and Chas. Cory & Son. The American Institute of Electrical Engineers not only allowed the use of articles published in the proceedings of that society, but very generously supplied several cuts to illustrate the article on the Gyroscopic Compass. Lieutenant Edward J. Foy, U. S. N., of the Bureau of Steam Engineering, rendered the greatest assistance in supplying information in regard to recent changes and improvements in electrical appliances.

The compiler wishes particularly to thank Gunner R. O. Williams, U. S. N., for his valuable assistance in collecting information for the sheets of notes and corrections and assisting with the manuscript in many ways.

J. T. Tompkins,
Commander U. S. Navy.

March 6, 1915

PREFACE TO FOURTH EDITION

VOLUME II

The many developments and improvements in the electrical material and apparatus and the great extension of the use of electricity on ships of the Navy have rendered necessary a revision of this volume.

Captain W. H. G. Bullard, U. S. Navy, the author, was unable to undertake this revision on account of important duties elsewhere. The revision was accordingly undertaken by the Head of the Department of Electrical Engineering and Physics with the aid of the assistants of that department. Credit is particularly due to Lieutenant R. S. Edwards, U. S. Navy, who performed a large part of the work on this volume; also to Lieutenant Commander H. G. S. Wallace, U. S. Navy, Lieutenant W. W. Turner, U. S. Navy, and Instructor J. B. Arthur, who rendered material assistance.

In accordance with the original plan of the book only the practical applications of electricity on board ships of the Navy have been treated in Volume II. No attempt has been made to describe all the electrical apparatus used, but typical installations have been described in detail to illustrate the applications of electricity in the service, and to show how the electrical problems encountered have been solved.

The elimination of much matter descriptive of material and methods that have been superseded and the addition of later developments and new uses of electricity has involved rewriting a large part of the book.

The compiler desires to express his appreciation of the assistance rendered by many officers in the service, and particularly to Commander E. P. Jessop, U. S. Navy, Engineer Officer of the Navy Yard, New York; to Lieutenant Commander S. M. Robinson, U. S. Navy, and Lieutenant A. Sharp, Jr., U. S. Navy, of the Bureau of Steam Engineering; and to Naval Constructor A. H. Van Keuren, U. S. Navy, of the Bureau of Construction and Repair, for their valuable assistance in supplying information in regard to recent changes and improvements in electrical equipment. It is also desired to acknowledge the courtesies extended by the following manufacturers: The Cutler-Hammer Manufacturing Company, the General Electric Company, the Westinghouse Manufacturing Company, the Holtzer Cabot Electric Company and The Submarine Signaling Company, all of whom have freely furnished much valuable information and data.

G. S. Lincoln,
Commander U. S. Navy.

May 15, 1917.

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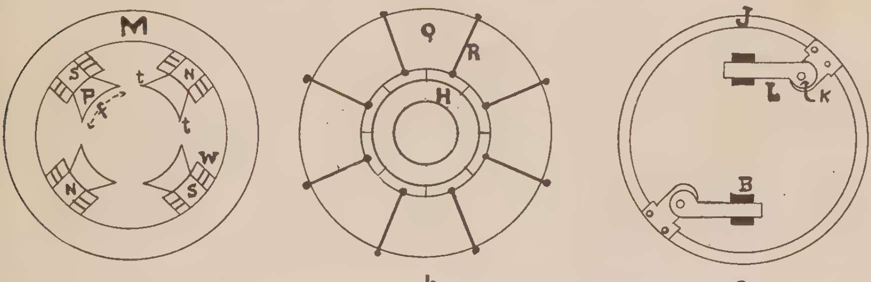
CHAPTER I.

THE CONSTRUCTION OF THE DYNAMO.

The dynamo electric machine, or, simply, the dynamo, is a machine for converting electrical power to mechanical power or vice versa. When used for the former purpose, the dynamo is called a motor; when used for the latter purpose, it is called a generator, though the term dynamo is often loosely used for generator. An example of this is the name of the compartment in which the generators are installed on board ship, which is always called the dynamo room. Any direct current dynamo may be used either as a generator or as a motor, but the machines used in the naval service, with the exception of the main motors of submarines, are designed to be used only as motors or only as generators. The differences in construction are, however, slight.

ESSENTIAL PARTS OF THE DYNAMO.

Fig. 1 shows all the parts essential to any dynamo of the type commonly used on board ship for direct current generators and motors.



a b c

Fig. 1.—Elementary Diagram of Essential Parts of the Dynamo.

Fig. 1a shows the **Field Structure**, formed by the *field magnet frame* or *yoke* M and the *poles*. The *poles* consist of the *field cores* S N, the *pole pieces* P and the *field winding* or *field coils* W. The surfaces *f* of the pole pieces are called the *pole faces*, and the edges *t* the *pole tips* or *horns*.

Fig. 1b shows the **Armature**, which is mounted on a shaft, and consists of the *core* Q, the *armature winding* R, and the *commutator* H.

Fig. 1c shows the **Brush Rigging**, consisting of the *rocker ring* or *brush yoke* J, the *brush holders* L, and the *brushes* B. The brush holders are secured to brackets on the rocker ring by *brush studs* K.

FUNCTIONS OF THE PARTS OF THE DYNAMO.

Field Structure.—The function of the *field magnet frame,* the *field cores,* and the *pole pieces* is to form, with the *armature core* and the *air gaps,* the magnetic circuit. It is important to reduce the reluctance of this circuit as much as possible, and materials are selected and the parts shaped with this end in view. The *magnet frame* supports the *poles.* The *field cores* are the parts of the poles which carry the field windings, and the *pole pieces* are the parts of the poles so shaped as to render as nearly uniform as possible the magnetic field in which the armature revolves. The *field winding* carries the exciting current which produces the magnetic flux. *Interpoles* are similar to main poles in construction, and their function is to overcome the effect of armature reactions so as to secure sparkless commutation on change of load, without the necessity for shifting brushes. Interpoles are referred to as "interpoles," "commutating poles," or "auxiliary poles," although the machines to which they are fitted are called interpole dynamos. The field structure also includes the *series shunt* and the *interpole shunt.* These are variable resistances in parallel with the series and auxiliary field coils, and their function is to regulate the proportion of the armature current flowing in these coils.

Armature.—The *core,* as stated, forms part of the magnetic circuit. It also supports the *armature winding* which carries the armature current. The function of the *commutator* is to rectify the armature current.

Brush Rigging.—The *rocker ring* carries the *brush studs* to which the *brush holders* are attached. The rocker ring is mounted concentrically with the commutator, and is usually constructed so that it may be rotated to bring the brushes into the commutating axis. The brush holders carry the *brushes,* whose function is to make a sliding contact with the commutator.

CONSTRUCTION OF THE PARTS OF THE DYNAMO.

The **Field Magnet Frame** is constructed of material having good magnetic properties. Cast iron was formerly used, but with improved methods of manufacture, cast steel, magnetically superior, but more expensive and more difficult to mould, is now being used extensively. The frame is usually circular in shape, though sometimes the octagon or similar modifications of the circle are used. In small machines the frame is in one piece, while in large dynamos it is divided into two parts so that the upper half can be lifted off to permit removal or examination of the armature. The lower part carries the feet or lugs for securing the frame to the bed plate. Bosses are cast on the inside of the frame and machined to form seats for the field cores. A block of insulating material called the *connection board* is usually mounted on the magnet frame to support the terminals of the various circuits.

The Poles.—*Field cores* and *pole pieces* are made of highly magnetic material such as steel or wrought iron, the latter being the best magnetic substance available. For small poles the cores are sometimes solid, but the laminated type is the most frequently used. The laminations of cores and pole pieces are made thin and insulated from each other by varnish or by leaving the mill scale on them. They lie perpendicular to the direction in which eddy currents tend to flow and so prevent, practically, the formation of such currents and the consequent power waste. Furthermore, the laminated construction insures a uniform quality of metal throughout the entire pole, which tends to produce a better distribution of the magnetic flux and to insure equal magnetization of all poles. With a cast pole internal flaws and blow holes may increase the magnetic reluctance of one pole over another and cause electric unbalance in the completed machine. The pole pieces are shaped concentric with the armature. The tips extend out on both sides, encircling the armature to properly form the magnetic field and to support the field coils. The pole pieces are sometimes made separately and bolted to the cores and sometimes made in one with the latter as shown in Fig. 2. A special type of pole piece, used on large Diehl motors, is formed by extensions of the core laminations, the extensions having alternate right and left projections to form the tips (Fig. 3). The area of a tip is half that of the solid type and is, therefore, more easily saturated. This construction resists the tendency for the flux to crowd at one tip under the influence of the armature reactions and so gives a more even distribution of the field.

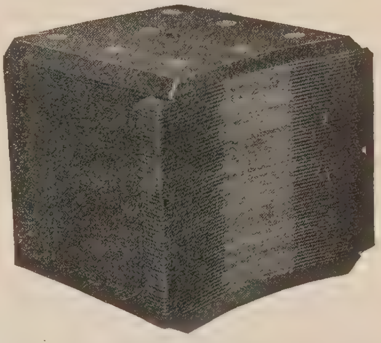
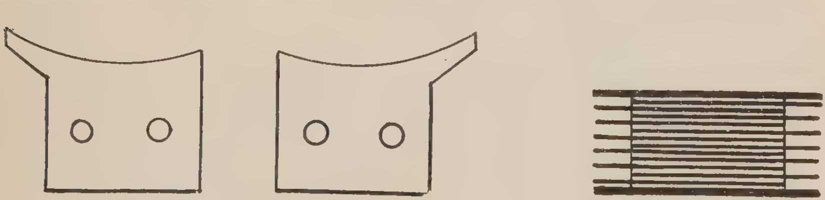


FIG. 2.—Laminated Field Core and Pole Piece.



Alternate Laminations.

Pole Face.

FIG. 3.—Motor Pole Construction. Diehl Elec. Mfg. Co.

Field Winding.—Field windings are of copper wire, ribbon, strap, or bars, depending on the strength of the current they are required to carry. They are usually *form wound,* that is, the insulated conductor is wound on a bobbin or form of the same shape as the field core. After winding the form is removed and the coil is taped and finished. The object is to have each coil a separate unit that may be readily removed from the field core and replaced by a spare coil in case of damage. The finishing process consists in dipping the coil in a waterproof insulating compound, or in subjecting it to *vacuum impregnation.* In this process the completed coil is placed in a tank from which the air is exhausted until a very high vacuum is obtained, this insuring that all moisture is drawn off from the interior of the coil. Hot insulating compound is then forced into the tank under pressure and penetrates the coil, saturating it down to the innermost layer. The vacuum existing in the coil prevents the formation of air bubbles in the insulation, and the coil, when removed and dried, is a solid moisture-proof mass in which the copper wires are imbedded. The coil after impregnation is thoroughly taped and varnished and is then ready for assembly in the machine. In older construction the shunt and series windings of compound dynamos were sometimes wound together on one bobbin and formed a single unit, but, to secure better ventilation, the modern practice is to wind each as a separate unit. Figs. 4 and 5 are examples of wire wound coils and Fig. 6 of strap wound coils. It should be noted in these illustrations that the ends of the winding are brought out through the insulation, the object being to permit connection to be made without in any way disturbing the insulation of the coil. Fig. 7 is an example of a new type of field winding used on large dynamos where the prevention of overheating of the field coils is a problem. The shunt winding is form wound

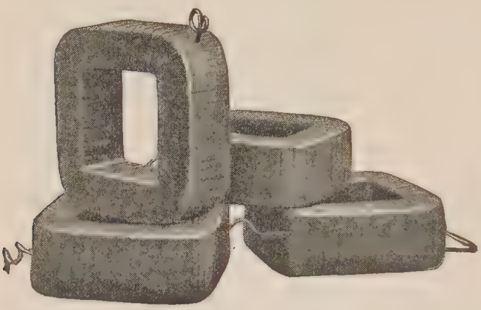


FIG. 4.—Wire Wound Field Coils.

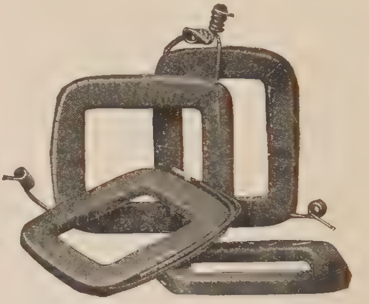


FIG. 5.—Wire Wound Field Coils.

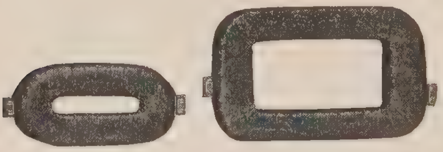


FIG. 6.—Strap Wound Field Coils.

and impregnated, and an air space is provided between the shunt coil and the field core. The series coil is of bare copper strap wound edgewise around the shunt coil and separated from it by air space. The rotation of the armature causes a circulation of air around the coils, preventing overheating.

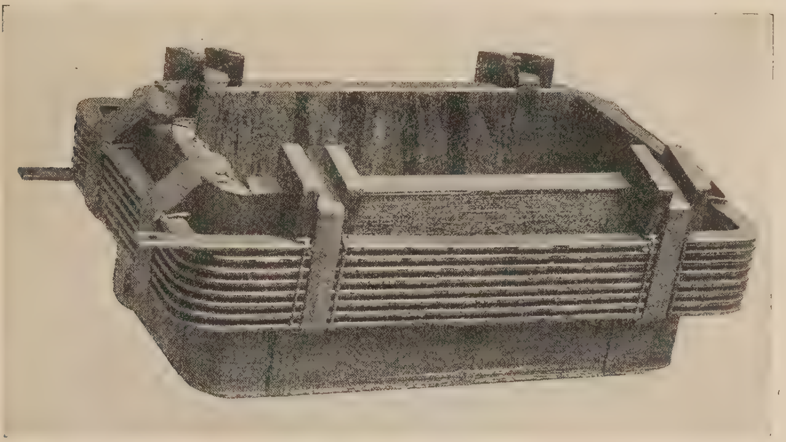


Fig. 7.—Field Coils of Large Compound Dynamo.

Assembly of Poles.—The pole pieces, if not in one with the cores, are bolted to them. The cores are secured to the frame by bolts. The coils are slipped over the cores and secured tightly to prevent vibration and consequent chafing of the insulation. One method of pole assembly is shown in Fig. 8. The unit at the left is the core with the pole piece attached. The coil fits around the core and is held in place by the spreading pole piece. The heavy, flat steel spring shown at the right is inserted between the coil and the magnet frame. The bolts attached to the core pass through the magnet frame and are set up by means of nuts from the outside, pressing the coil firmly between the spring and the pole piece. Another method of pole assembly is illustrated in Fig. 9, in which a steel washer is used in place of the spring, the larger coil here used having itself sufficient elasticity to stand

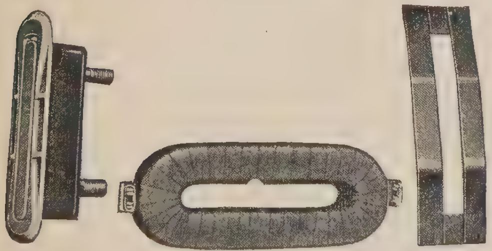


Fig. 8.—Assembly of Strap Wound Commutating Pole.

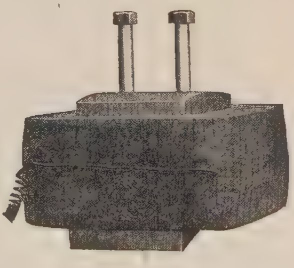


Fig. 9.—Assembly of Wire Wound Main Pole.

firm compression without crushing. The leads from the field coils are connected after the completed pole is secured in place, each field circuit having a terminal on the connection board, which also sometimes carries the terminals for the series and the interpole shunts. The shunts are of German silver or a similar alloy of low temperature coefficient and are adjusted in the test runs of the machine, the series shunt to give the compounding desired, and the interpole shunt to give the proper excitation to the interpole field. These adjustments are permanent and under ordinary circumstances need never be altered while the machine is in service. The interpole shunt has an inductance at least as great as the inductance of the interpole coils, in order that the sudden increase of current due to a short circuit may be accompanied by a corresponding increase in the commutating flux; if the shunt were non-inductive, an increasing current would avoid the high reactance of the coils. The series shunt has a low inductance in order that a rush of current, due to a short circuit, may avoid the series winding, and so not make a bad matter worse by raising the terminal voltage.

Armature Cores should be of magnetic material in order to concentrate the field flux and to decrease the reluctance of the magnetic circuit. The retentivity of the material should be small, that the loss by hysteresis may be minimized. Accordingly, armature cores are constructed of soft wrought iron or mild steel. To reduce the effects of eddy currents, the cores of armatures, like those of field magnets, are laminated in thin discs, insulated from each other by coatings of varnish and sometimes by shellac or paper. The laminations are perpendicular to the axis of rotation of the armature; that is, perpendicular to the general directions in which eddy currents tend to flow. Such process does not entirely prevent loss by eddy currents, as small currents will still form in each disc, but the thinner the discs the less will be the loss. If, however, the discs are made too thin the power saved through eddy current reduction will be overbalanced by the loss introduced through the decrease of the magnetic area of the core by the space utilized for the insulation.

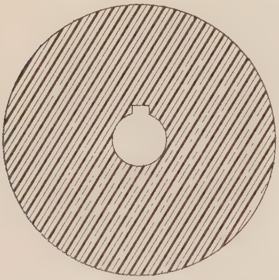


FIG. 10.—Armature Core Disc [Smooth Core].

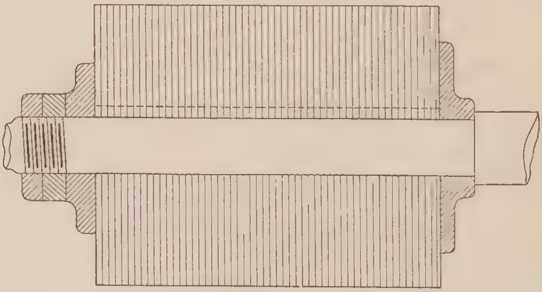


FIG. 11.—Armature Core.

For small armatures the discs are punched in one piece and are mounted directly on the armature shaft and keyed to it. Flanges and locking nuts on the shaft press and hold the discs together. Figs. 10 and 11 illustrate the construction.

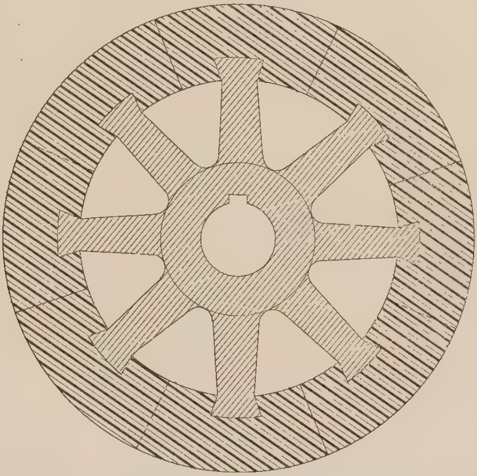


FIG. 12.—Spider Carrying Core Segments.

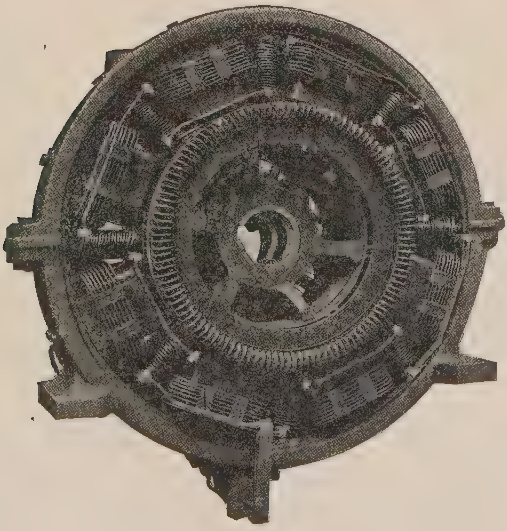


FIG. 13.—Showing Open Construction of Armature.

For large armatures the discs are built up of segments assembled on an iron spider (Figs. 12 and 13), the spider being pressed on and keyed to the armature shaft. Successive joints in the laminations are staggered.

The laminations are separated at intervals, thus forming radial air ducts which permit the radiation of the heat developed by eddy currents and the armature current. Spacing pieces are interposed between the separated laminations, insuring the rigidity of the core. Fig. 14, showing one radial air duct, illustrates how the armature is ventilated. The rotation of the armature causes air to pass in through the spider openings, and out through the air ducts and through the overhanging ends of the armature coils, as indicated by the arrows in the accompanying figure. From the armature the air is blown outward against the pole faces and around the field coils, thus keeping all the active parts of the electric and magnetic circuits cool.

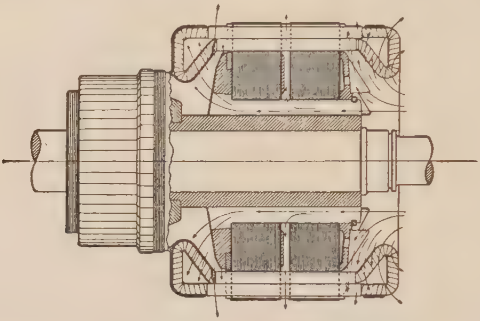


FIG. 14.—Cross-Section of Armature, Showing Method of Ventilation.

The laminations are usually soft steel punchings. They are assembled under heavy pressure and held securely in place by flanges, heads, or end rings on the spider. Fig. 15 shows a spider with head and end ring. The commutator is generally mounted on an extension of the spider, although sometimes it is carried on the armature shaft. The advantages of the spider armature construction are as follows:

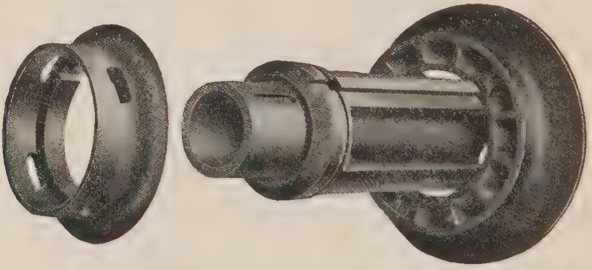


FIG. 15.—Armature Spider and End Ring.

(a) It permits the easy removal of a bent or damaged shaft without disturbing the armature winding.

(b) The spider so reinforces the shaft that there is little danger of springing or breaking the shaft in service.

(c) Building the core on the large diameter of the spider reduces the strain on the keys. The shaft is forced into the spider with a pressure that causes expansion, takes up all looseness and minimizes the possibility of the core getting loose on the shaft.

(d) It insures keeping the armature core and commutator in the same relative position and eliminates all breakage of leads due to shifting of the commutator with respect to the core, besides making it practically impossible for the commutator to loosen on the shaft.

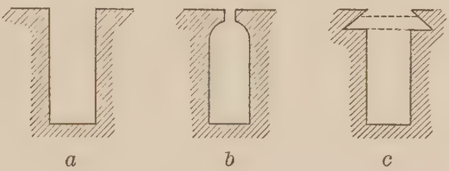


FIG. 16.—Armature Slots.

Armature core discs are now made with deep slots for receiving the armature inductors. Smooth cores, as illustrated in Fig. 10, were formerly used, the inductors being carried on the surface of the core and bound there. This arrangement interposed a thick layer of copper and air, both non-magnetic, between the core and the pole faces, thereby adding to the reluctance of the magnetic circuit of the dynamo. Furthermore, the exposed inductors were liable to mechanical injury, and the armature drag was likely to displace them when the armature current was heavy. With a slotted core the inductors are securely held in place and protected and the air gap may be reduced.

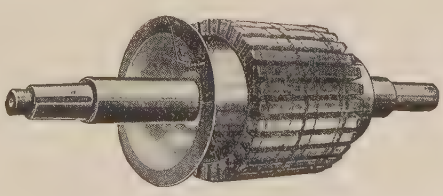


FIG. 17.—Slotted Armature Core.

Three types of armature slots are generally employed. Fig. 16 shows examples of each. The open slot *a* is the usual construction for the direct current machines. It facilitates the winding of the armature. The partly closed slot *b* simplifies securing the windings. The slot *c* is fitted with a recess at the top to permit the insertion of wooden wedges to hold the inductors in place.

Fig. 17 is a photograph of a slotted armature core. Fig. 23 is a photograph showing the armature core with its commutator. The space between the core and flange at the back and between the core and commutator at the front is for receiving the overlapping ends of the armature coils. The radial ventilation ducts and their spacing pieces are shown.

Armature Windings are of copper, either as wire or in bars. Armatures are wire wound, generally, when their current output is small, and bar wound when their current output is large. The coils or sections of an armature winding are formed individually and are interchangeable. Coils of this type are called "**form wound.**" A damaged coil may be removed and replaced without entirely rewinding the armature. The several conductors or turns that constitute a coil are insulated separately, using mica, cotton or linen tape, insulating compound, or varnished cloth or paper. They are then fastened together and wrapped with a few layers of insulating tape, occasionally providing first a mica covering, and the whole is filled and sealed by dippings in moisture-proof varnish, or by vacuum impregnation. This protects the coil and gives it a finished appearance. Before the coils are placed in the slots the latter are generally lined with insulating materials, using mica, fiber or paper pulp. The core ends are insulated wherever the windings can touch them.

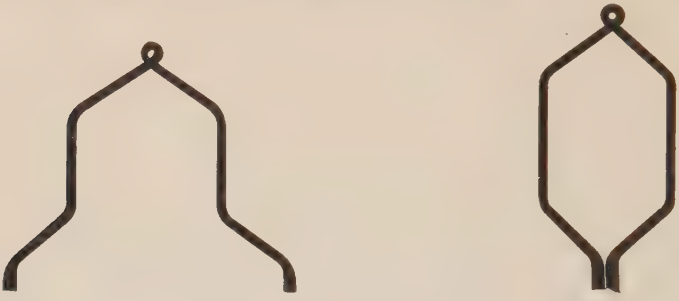


FIG. 18. FIG. 19.

Armature Coils.

Fig. 18 shows a one-turn coil or section of a wave-wound armature, and Fig. 19 the coil of a lap-wound armature. When the armature inductors are so large that they cannot be bent, each half of each turn is individually insulated and placed in its slot. A copper bridge is then soldered to the bare end of the inductors at the rear, thus completing the electrical circuit.

In large armatures the inductors are usually held in place by wooden or fiber wedges driven in the tops of the slots, as illustrated in Fig. 16 (c). With small armatures binding wires of phosphor bronze, brass, or steel, wrapped around the periphery of the core and insulated therefrom, secure the inductors. Some of the laminations are made of smaller diameter than the others to afford grooves for the binding wires, allowing the latter to sink below the surface of the core.

The ends of the armature coils which constitute the leads are brought out and soldered in the slots in the lugs of the commutator bars. Each coil is carefully tested for grounds and short circuits before connecting it to the commutator; the complete armature is also similarly tested. Both back and front connections of the coils are firmly bound to withstand the centrifugal force of the revolving armature.

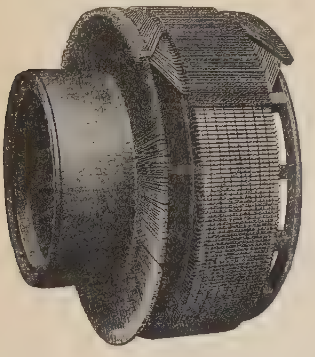


Fig. 20.—Partially Wound Armature.

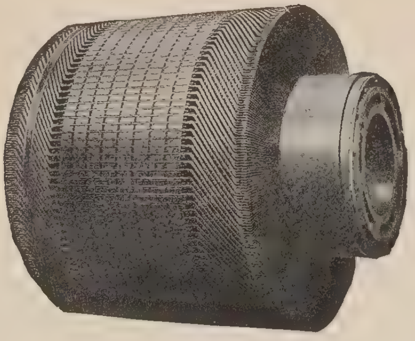


Fig. 21.—Complete Armature (Shaft Removed).

Fig. 20 illustrates the method of winding an armature. Fig. 21 shows the completed armature whose inductors are secured by fiber wedges driven in grooves in the core teeth. Fig. 22 shows a completed armature whose inductors are bound by bands of wire.

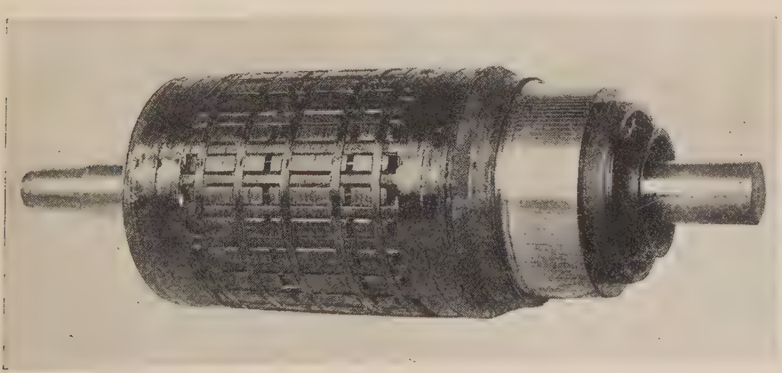


Fig. 22.—Banded Armature.

To limit the reactance voltage developed in the short circuited armature coils at commutation, the number of turns in each coil is usually not more than three for machines of moderate size. For the same purpose it is desirable to shorten the axial length of the armature coil, that the length and consequently the inductance of the inductors may be lessened. Shortening the core necessitates increasing its diameter to obtain equal power; but with large cores large commutators may be employed, with the advantage explained below.

The Commutator is formed of hard-drawn copper bars insulated from each other by mica segments. Besides being a good insulator mica has the added advantage of wearing at about the same rate as copper. The bars are assembled on and securely clamped to a steel bushing, from which they are insulated, also by mica. The bushing is pressed on a machined seat extending from the armature spider (in some cases on the armature shaft, as has been stated) and keyed, making the armature and commutator a unit. Each commutator bar carries a radial lug (see Figs. 23, 24 and 25) on the back end to which the leads from the armature winding are attached. Fig. 25 shows the shape of a bar longitudinally. *l* is the radial lug connecting with the armature winding. The bushing on which the bar is mounted clamps in the recesses, *rr*. In cross-section the bar tapers to an extent sufficient to make the complete commutator a compact cylindrical structure.

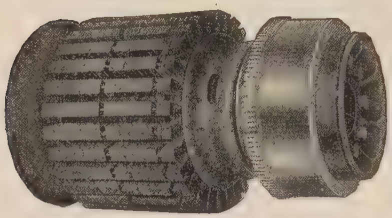


FIG. 23.—Armature Core and Commutator.

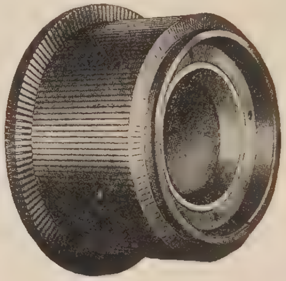


FIG. 24.—Commutator.

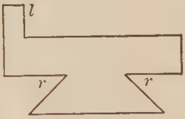


FIG. 25.—Commutator Bar.

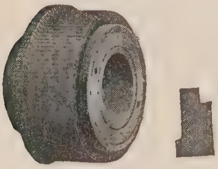


FIG. 26.—Commutator and Commutator Bar.

Another type of commutator having bars of slightly different construction is shown in Fig. 26.

The tendency of a dynamo to spark at the brushes depends in part upon the reactance voltage of the armature coils at commutation, and, in consequence, upon the number of turns in each coil. It is therefore desirable to employ commutators of large diameter, as these may carry many bars, permitting the reduction of the number of turns in the sections of the armature winding.

It is essential that the commutator should be smooth. A rough commutator causes vibration of the brushes, which in turn produces sparking with its loss of power and injury to the mechanism. Loose commutator bars have the same effect.

The Armature Shaft and Its Bearings.—Bearing housings on large motors and generators are usually supported by pedestals built up from the bed plate. Many machines, especially the smaller ones, have bearing housings secured to end bonnets bolted to the field-magnet frame. This difference in construction may be seen by referring to Figs. 34 and 47. Bearing liners are of bronze for small dynamos and of babbitt for large machines, but the use of hard bronze liners is being extended and they will be found on fairly large motors of recent construction. Self-oiling is almost universal and the *Oil Ring Type* of self-oiler is commonly employed for both generators and motors. Fig. 27 shows a single ring oiler. The oil ring lies loosely on the shaft and dips in the oil contained in the reservoir in the lower part of the housing. The ring, revolved by friction with the shaft, draws up a continual stream of oil which is distributed through the spiral grooves to all parts of the journal and collects in the circular grooves at the ends of the bearing, whence it returns to the reservoir through the drains.

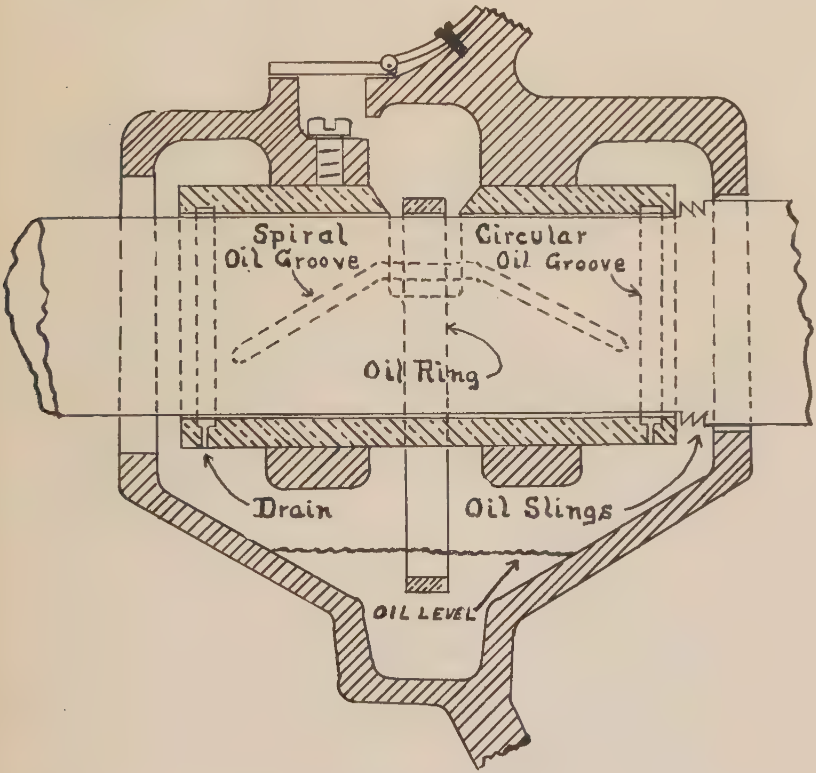


FIG. 27.—Single Ring Oiler.

Oil slings are turned on the shaft inside the bearing housing to prevent the escape of oil by creeping along the shaft. These knife edged slings throw the oil off by centrifugal action, the oil being readily detached as it climbs over the sharp edges, though it clings tightly to the smooth part of the shaft. On very low speed motors the edges of the slings have such a low peripheral velocity that they are not always effective in throwing off the oil, and as an additional precaution the face of the bearing housing is fitted with a leather washer which fits snugly around the shaft, acting like gland packing. The washer is secured to the housing by a brass retaining plate and screws.

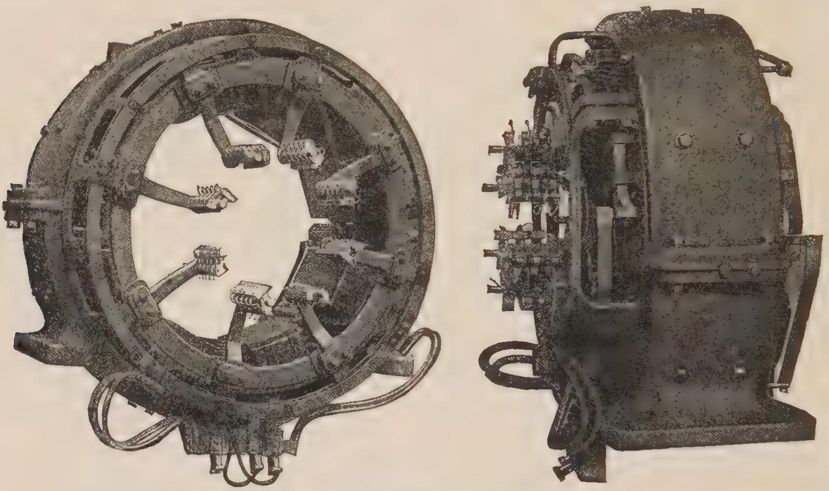


FIG. 28.—Field Frames Showing Rocker Rings and Brush Holders.

Brush Rigging.—The rocker ring carries the brush holders. This is a ring mounted concentric with the commutator and capable of being rotated. By it the brushes may be moved to the position of minimum sparking. Suitable mechanism for rotating the ring and clamping it firmly in any position is provided.

Brush holders support the brushes, pressing them firmly against the commutator. Springs form part of the brush holder mechanism, insuring that the contact of the brushes with the commutator is constant throughout the life of the brush and that it is not disturbed by an irregular commutator. The springs do not carry all the current, most of it being led from the brush to the stationary part of the holder by flexible connections. The holder is insulated from the dynamo frame. Devices for adjusting the tension of the springs are provided. Brushes are usually set at an angle with the surface of the commutator except for dynamos which reverse their direction of rotation, when they are set radially.

Fig. 28 shows eight brackets each carrying one brush stud, to which one brush holder carrying five brushes is attached. This arrangement would be described in specifications as a brush rigging with eight studs, five brushes per stud. The two smaller rings shown in front of the rocker ring are of insulated copper and are known as "bus rings." To one of them all the positive brushes are connected; to the other, all the negative brushes. The bus rings are connected to terminals on the connection board by flexible connections.

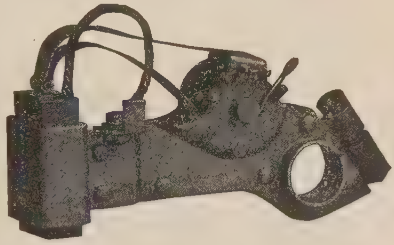


FIG. 29.—Brush Holder and Brush.

Brushes are now generally made of graphitic carbon in hard blocks. Formerly metal brushes, in the shape of a bundle of metal leaves or wires, were used, but these roughened the commutator, and, in consequence, they have been discarded except for low voltage dynamos, and the A. C. end of three wire generators where the resistance of carbon brushes would be too great. Carbon wears well mechanically, furnishing its own lubrication in the form of graphite, and, in addition, because of its high resistance, it decreases the tendency of the armature to spark at the brushes.

CHAPTER II.

SERVICE GENERATORS.

A generating set is the combination of an electric generator and its operating motive power. The combination is usually considered a unit.

All vessels built by or for the government are supplied with standard apparatus, manufactured under specifications prepared by the Navy Department. A few commercial type generators are to be found on colliers and other vessels of the train.

On older vessels the generators are comparatively small and driven by slow speed reciprocating engines. The steady advance in manufacturing skill is reflected in the gradual change in ships of later date. The generating sets are larger, the number of poles is greater; speeds are higher with the introduction of the turbine; interpole machines are used; while the latest battleships have the three-wire generator gear driven by a high-speed turbine.

DIRECT CURRENT GENERATORS.

All ships previous to the *Arizona* have direct current two wire generators. Eighty volts was the standard for many years, but ships later than the *Missouri* have 125 volt generators. With the line drops allowed by specifications, these generators supply lamps at about 123 volts and motors at 120 volts. Service generators are always compound wound, the practice being to specify that the change in voltage from no load to full load and back again (with field rheostat unchanged) shall be small, usually about two volts. This is as close as it is possible to come to theoretical flat compounding. Owing to hysteresis effects the compounding is not the same with an increasing load as with a decreasing load, as may be seen in Fig. 30. Note that

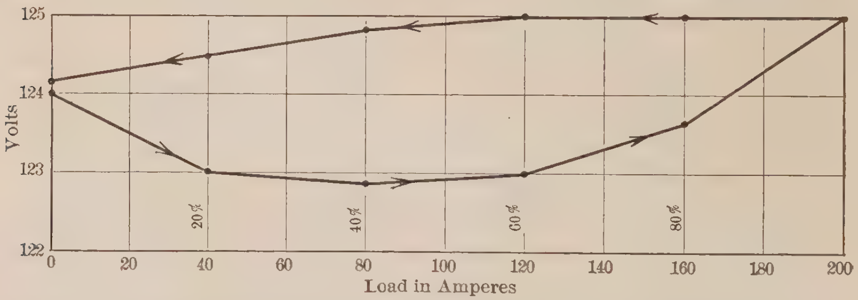


Fig. 30.—Compounding curve. Diehl 25 kw., 125-volt generator, U. S. S. *Porter*. Shunt field rheostat set to give 124 volts at no load. Load increased by 20 per cent steps to full load and back to no load without changing rheostat setting.

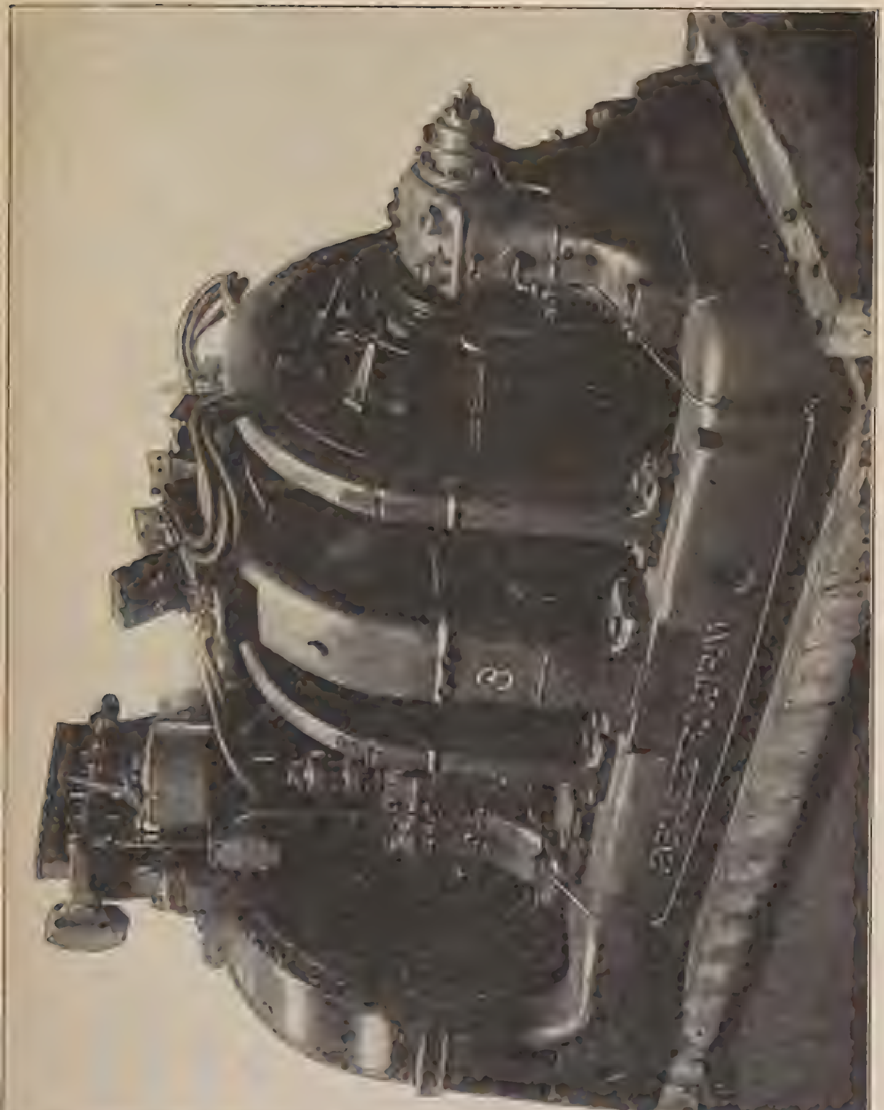


Fig. 31.—300 kw. Generator, U. S. S. *New York*

as the voltage is greater at full load than at no load the generator is overcompounded but the characteristic with increasing load is different from that taken with decreasing load, the greatest difference being about two volts.

Armatures are wave wound for sizes below 100 kw. and parallel wound for larger sizes. Except for a very few ring wound armatures on very old ships, the slotted drum type core is used.

The details of construction are covered in a general way in Chapter I. Dynamos used as generators are usually of more rugged construction than motors and the shaft bearings are supported in housings built up from a bed plate. The light, high speed generators supplied to destroyers and the generators of motor-generator sets have their bearing housings supported by end bonnets bolted to the field magnet frame, a form of construction that is typical of the motor.

The following descriptions of a few types of direct current generators cover all the important features of construction of service machines:

300 kw. Generator, U. S. S. New York.

General.—Four 300 kw., 125 volt, compound wound, six pole, interpole generators, direct connected to 1500 R. P. M. Curtis turbines.

Field Structure.—The frame is of cast iron, split on the horizontal center line. Main and commutating poles are of laminated sheet iron with bolted on pole pieces. The field coils are wound on bobbins which are not removed after winding. The winding for each main pole consists of the series turns of strap copper, upon which the shunt coils are wound.

Armature.—The distinctive feature of the armature is that it carries two separate windings, each connected to a commutator of its own (Fig. 32). The leads from the brushes are permanently connected in such a way that the two commutators are in parallel on the external circuit.

The armature core is supported by a spider keyed to the shaft and is of the laminated type with ventilating ducts as illustrated in Fig. 14. There are 90 slots insulated with asbestos paper and linen, each slot carrying two coils of each winding (four in all). Each coil is composed of three turns of annealed copper strap, form wound and impregnated. The winding is secured by 14 binding bands, each composed of a copper strap (to prevent the binding wires cutting the insulation) on which steel wire is wound. The completed armature is treated while hot with an oil varnish, which is then baked until hard.

The commutators are mounted on the shaft, one at each end of the armature. The commutator construction is that illustrated in Figs. 24 and 25, except that the mica between the segments is undercut to insure that slight centrifugal movement of the insulation or wear of the copper will not cause the mica to extend above the surface of the commutator, and make the brushes chatter and spark.

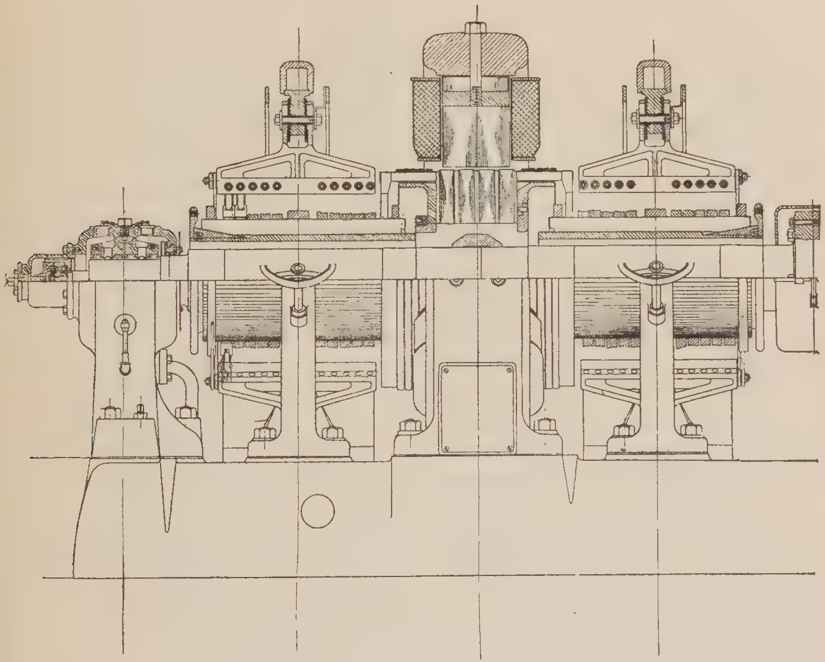


FIG. 32.—Armature and Commutator, 300 kw. Generator.

Each commutator has four equalizer circuits formed of copper ribbon, soldered to commutator leads 120° apart. A diagrammatic sketch of the method of connecting these balance or equalizer rings is shown in Fig. 33.

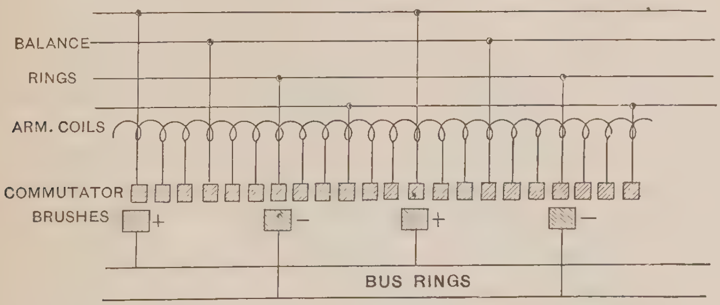


FIG. 33.—Elementary Diagram of Equalizer Circuits.

The object of the equalizer rings is to connect together equipotential points in the armature winding. The necessity for them arises from the practical impossibility of securing equal flux from all poles. If the bearings wear down the air gaps become of unequal length; slight differences in the permeance of field cores, and variations in winding also affect flux. So the various parallel sections of armature winding never generate exactly equal voltages and, consequently, do not supply equal shares of the total armature current. Hence, if there were no equalizer circuits, some of the brushes would carry more current than they are designed for, and would spark. The function of the equalizer rings is to form common terminals for the armature circuits inside the brushes. The brushes are then in parallel between the equalizer rings and the bus rings and so carry equal currents. To exactly equalize the currents every commutator segment should have an equalizer connection. This would require a large number of balance rings and, in practice, only enough rings are fitted to keep variation in brush currents within the limits set by the danger of sparking.

It should be noted that the function of equalizer circuits is merely to equalize brush currents; they do not prevent unequal currents in sections of the armature winding if unequal voltages are generated in these sections. They are, of course, applicable to parallel wound armatures only, their functions being fulfilled by armature coils in wave winding.

Brush Rigging.—The rocker ring is mounted in, and supported by, a yoke which is bolted to the bed plate. The ring is made with six brackets projecting inward carrying the brush studs to which the brush holders are bolted. Flexible leads from the brushes connect to copper bus rings, one for the positive and one for the negative brushes. From each bus ring flexible conductors lead to a terminal board on the magnet frame, where the two commutator circuits come together and form one circuit, from which connections lead to field coils and the switchboard. A double throw galvanometer, connected across the two commutator leads, is mounted on the magnet frame and indicates the difference in voltage between the two commutators. When this galvanometer reads 0, the generator is operating properly. If the two leads are not at the same potential, current will flow through the galvanometer and the deflection of the needle will indicate bad brush setting or spacing on one commutator, or some other cause of low voltage, such as dirt under the brushes or loose connections.

100 kw. Generator.

Fig. 34 shows the 100 kw. generator which is the next earlier type. This has but one commutator and a single armature winding. A cross-section is shown in Fig. 35. The differences in construction are slight and are noted below:

Poles.—No commutating poles.

Field Coils.—Shunt and series coils are form wound, each coil separately.

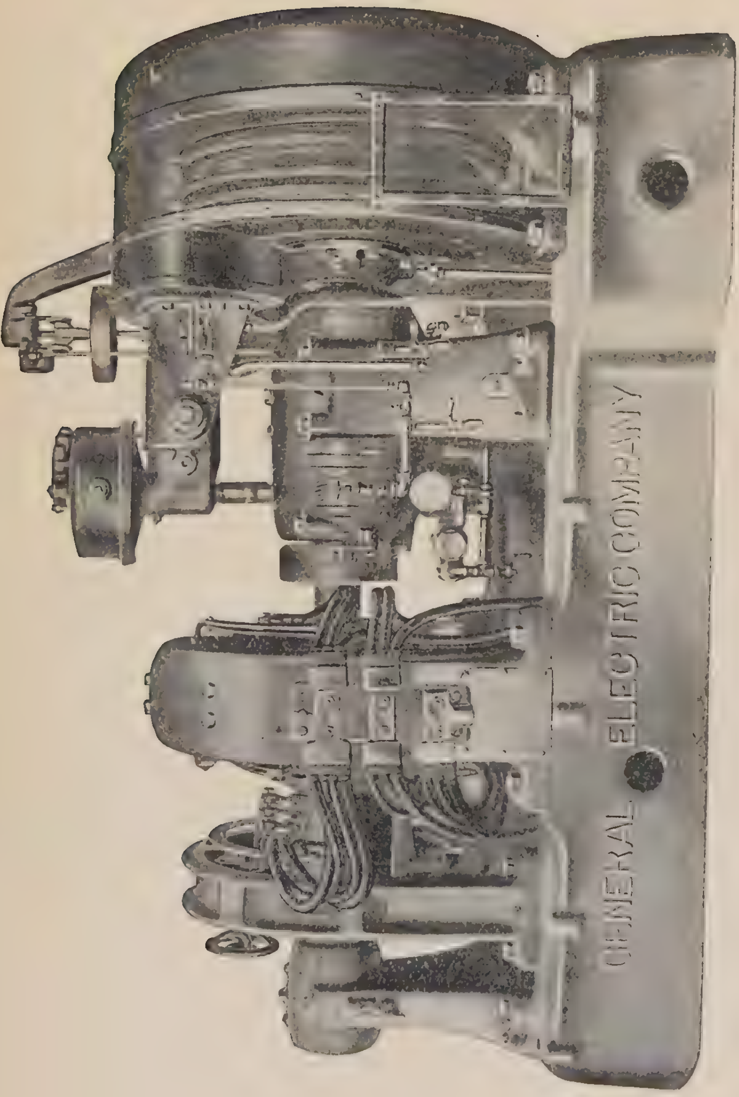

GENERAL ELECTRIC COMPANY

FIG. 34.—100 kw. Generator.

The shunt coil is put on the field core first, and the series coil slipped over it. The coils are held in place by the projecting pole pieces.

Armature.—Simple lap winding, coils secured by six binding bands, the end bands of steel wire and the others of phosphor bronze wire.

Brush Rigging.—Much the same as the 300 kw. machine, except that the single commutator requires fewer connections on the field magnet frame.

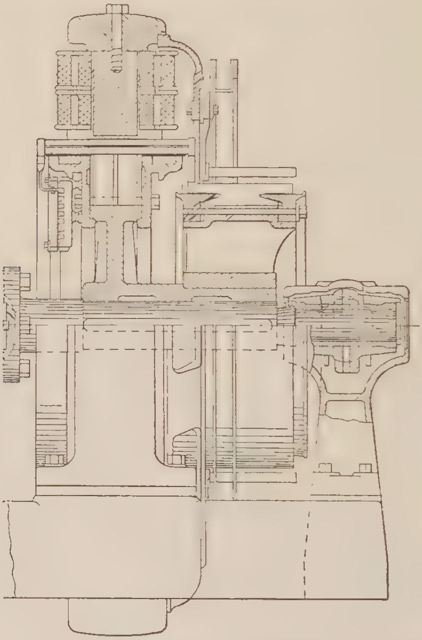


FIG. 35.—Cross-Section of 100 kw. Generator.

Earlier Types.

Earlier types have wave-wound armatures and are smaller and designed for lower speeds. An example of a rather early type is shown in Fig. 36. This is an 80-volt generator driven by a cross-compound engine. The principal difference between this and the later types is the head board on the magnet frame, which carries the terminals, pilot lamp, series shunt and circuit breaker. The pilot lamp is in parallel with the shunt field circuit and its function is to indicate when the shunt field is excited.

Generators for Destroyers.

Previous to 1908 the generating plant for destroyers consisted of one 5 kw. generator, driven by a reciprocating engine. Then a 5000 R. P. M. turbine driven, 5 kw. machine was adopted. The size was later increased to 10 kw.

and then to 25 kw., the speed being decreased for the larger sizes. All these generators are identical in principle with larger units, but ruggedness in construction is sacrificed to some extent to save weight and space.

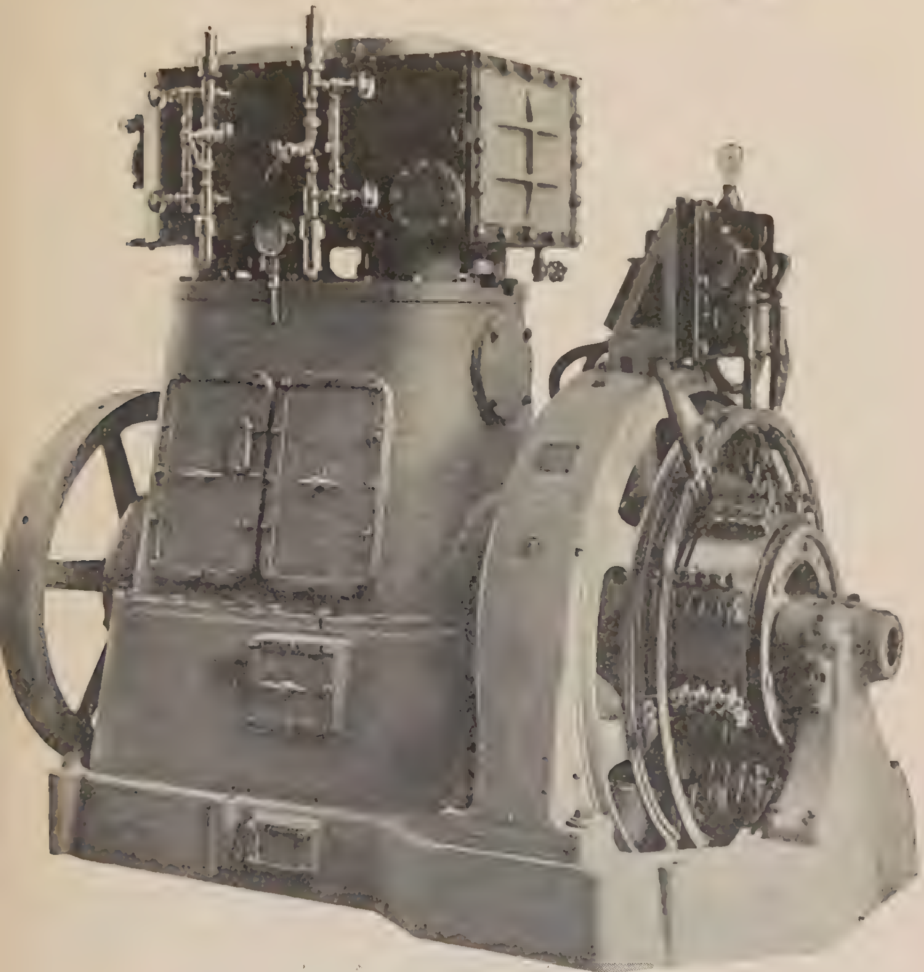


FIG. 36.—32 kw., 80 Volt Generator.

A description of one of the later types follows:

25 kw. Generator, U. S. S. Stockton.

General.—Two 25 kw., 125 volt, four pole, compound wound, interpole, Westinghouse generators, driven at 1200 R. P. M. through reduction gears by 7200 R. P. M. Westinghouse impulse type turbines are installed.

Field Structure.—(See Fig. 37.) The field magnet frame is made from a single open hearth steel bar, hot rolled into circular form, with the ends welded together. The feet are riveted on. The main poles, four in number, have cores of laminated steel and are bolted to the frame. The two interpoles have solid steel cores. All field coils are form wound and vacuum impregnated.

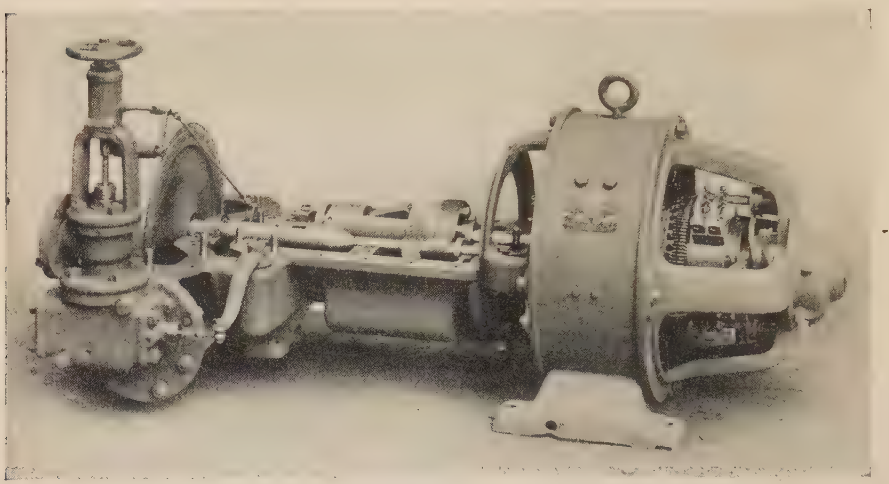


FIG. 37.—25 kw. Generator, U. S. S. *Stockton.*

Armature.—The core is of the slotted type, laminated, and ventilated by radial ducts. The commutator bushing is pressed into a recess in the end plate of the armature spider. Armature coils are form wound and are secured in the slots by wedges and two binding bands (Fig. 38). The finished armature is vacuum impregnated. The commutator is of the usual

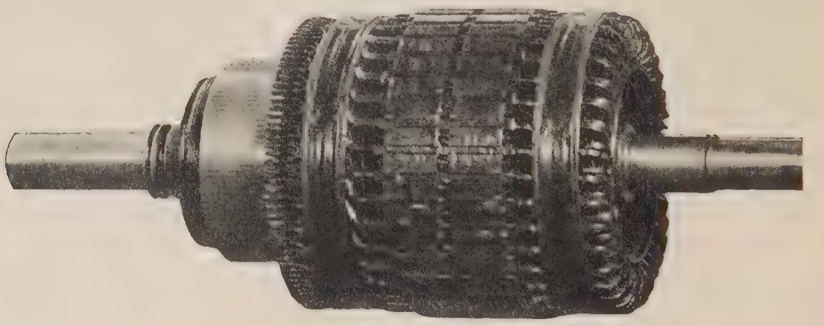


FIG. 38.—Armature of Westinghouse 25 kw. Generator.

construction. The shaft bearings are supported by end bonnets of cast iron, bolted to the field magnet frame. Bearing housings and oil wells are cast in one with the end bonnet.

Brush Rigging.—There is no rocker ring. Sherardized cold rolled steel brush studs are pressed into holes in the end bonnet, and support the brush holders. The holes for the bolts that secure the end bonnet to the frame are elongated (see Fig. 37) and allow the bonnet to be rocked to set the brushes. The brush setting is determined in the original assembly of the machine and no change in the setting is required in operation. All connections are made on a terminal board on the magnet frame. These connections are shown in Fig. 39, which illustrates a generator identical in type with that shown in Fig. 37, except in the arrangement of brushes.

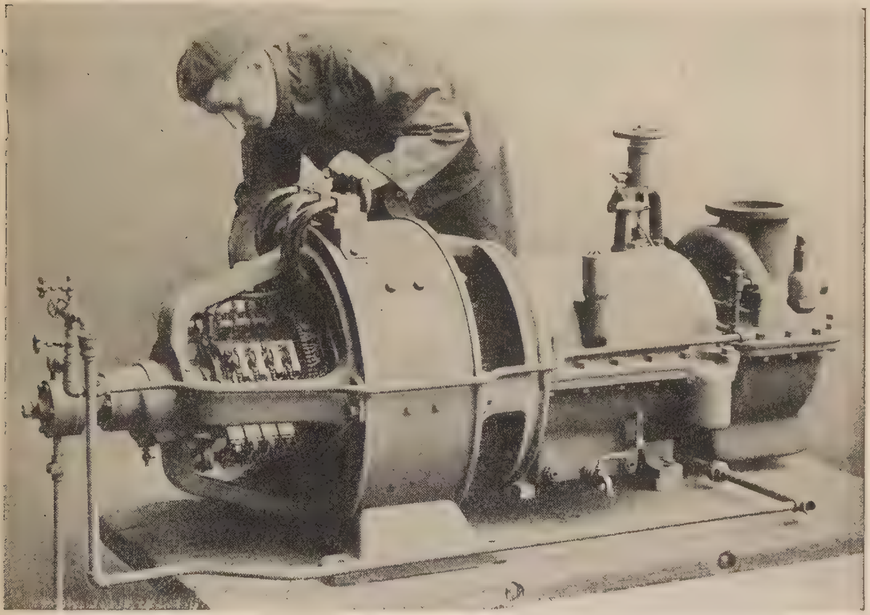


FIG. 39.—Westinghouse 25 kw. Generator.

25 kw. Generator, U. S. S. Porter.

This set is built to the same general specifications as the one just described and is of the same rating. It is manufactured by the Diehl Electric Company, and differs from the Westinghouse set in being direct connected to a 3200 R. P. M. turbine, in having a cast steel frame, and in having four, instead of two, commutating poles.

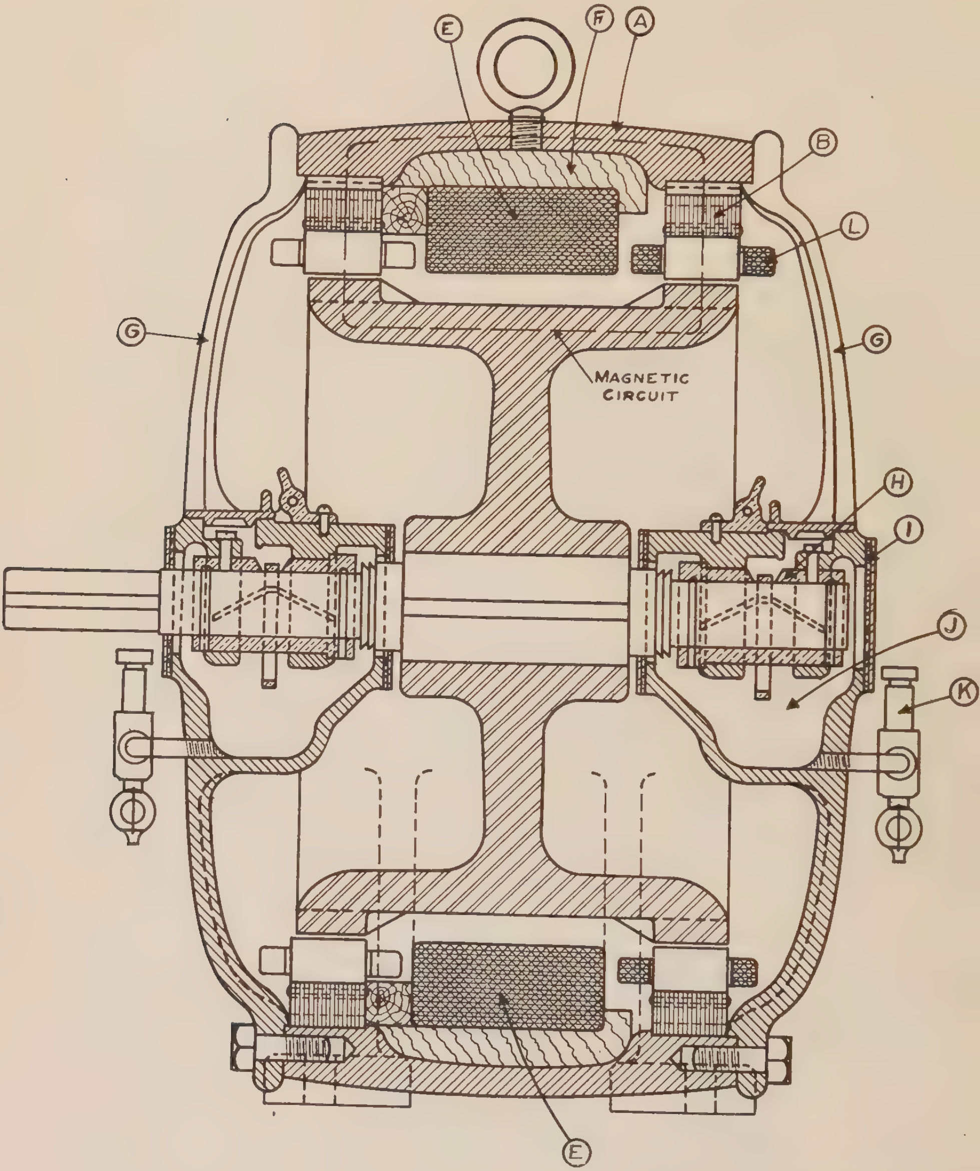
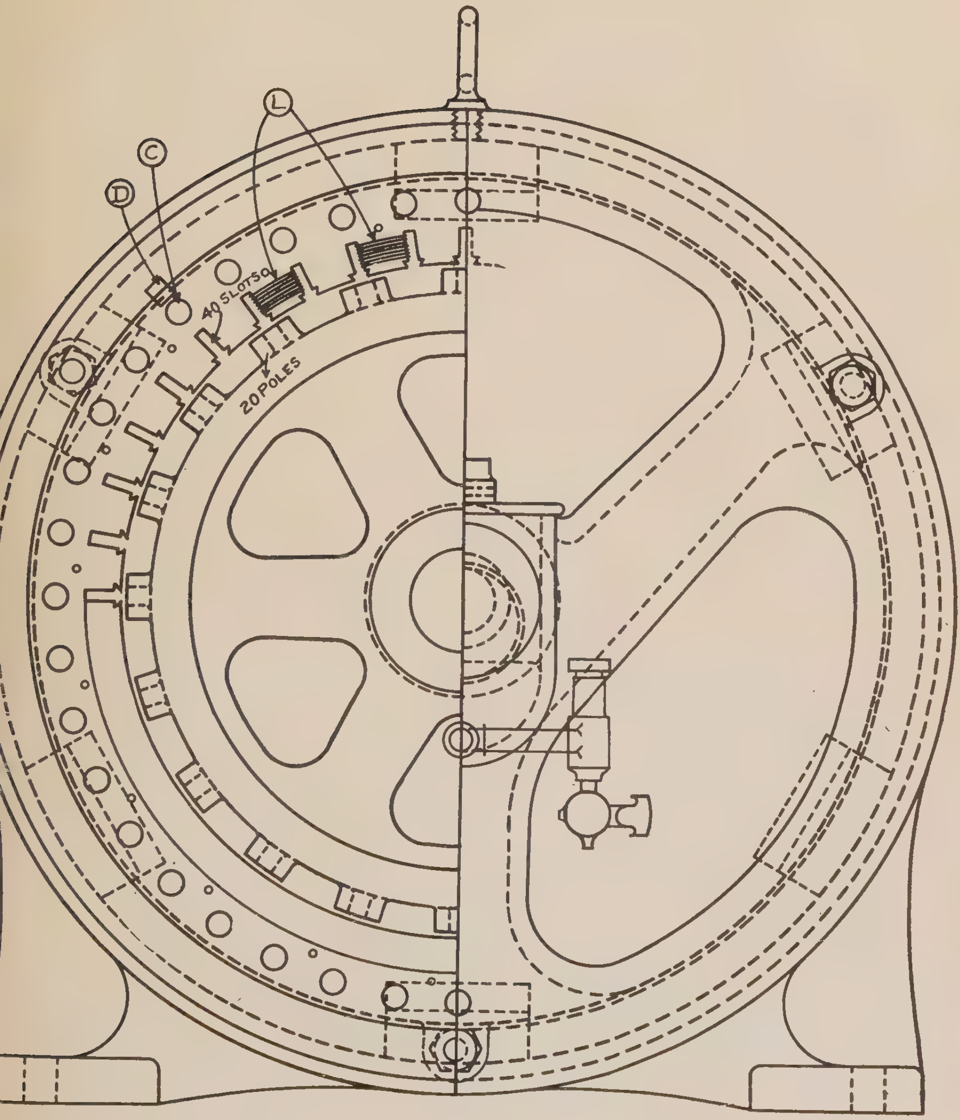

E
F
A
B
L
G
G
MAGNETIC CIRCUIT
H
I
J
K
E

FIG. 40.—Diehl 2 kw., 500 Cycle,


L
C
D
40 SLOTS
20 POLES

e-Phase Inductor Alternator.

ALTERNATING CURRENT GENERATORS.

Except in connection with electric ship propulsion, described in a later chapter, the use of alternating current generators on board ship is confined to gyro-compass installations and radio sets. Radio alternators are always driven by direct-current motors supplied from the ship's mains. The standard sizes are ½, 1, 2 and 5 kw., and the standard frequency is 500; though motor generators of greater capacity and other frequencies are in use.

The inductor type alternator with stationary field and armature windings is the one most frequently used. The advantage of this type is the absence of moving conductors, making a very rugged construction possible. The disadvantage is low efficiency on account of the large iron losses.

The Diehl machine described below illustrates the principle of the inductor alternator.

Diehl 2 kw., 500 Cycle, Inductor Type Alternator.

The 2 kw., 110/220 volt, 1350/1800, R. P. M., single phase, alternating current generators developed for radio work for the United States Navy by the Diehl Manufacturing Company are of the double armature inductor type.

The frame A (Fig. 40) is circular in shape and made of cast iron. There are two stationary armature cores B made of laminated circular rings secured in seats bored at each end of the frame. The laminations are held together by rivets C, and the completed core is held from turning by the key D. The armature cores are notched and the armature coils L are wound in the slots as shown. On one armature the coils are wound thus: coil one in slots 1 and 2, coil two in slots 3 and 4; while on the other armature, coil one is wound in slots 2 and 3, coil two in slots 4 and 5, etc. Each armature consists, therefore, of a number of projections from the armature core alternately bare and wound, the bare projections of one armature being directly opposite the wound projections of the other armature. Each armature carries 20 coils connected in series.

The field is a circular coil E, concentric with the shaft and supported in the frame between the two armatures by means of wooden blocks F. The field is excited by direct current at 120 volts. The inductive action is accomplished by the revolving central body of cast steel which has 20 projecting teeth known as the poles. The exciting coil sets up a field like that of any solenoid, the magnetic circuit being composed of the steel central body, the armature core, and the frame. The amount of flux threading any one of the armature coils depends on the reluctance of the magnetic circuit through that coil. The reluctance is least when *a pole* is directly under the coil and greatest when *the space between poles* is directly under the coil. The variation in flux induces an alternating E. M. F. in each coil, which completes a cycle during the passage of one pole and one blank across the coil. Since there are 20 poles, the E. M. F. in each coil completes 20 cycles in one revolution of the central body. Therefore, at 1500 R. P. M. (25 R. P. S.) the frequency is 500 cycles per second. Each armature consists of 20 evenly spaced coils and, there being 20 poles, the E. M. F.'s of the coils are in phase. Consequently, each armature delivers a single phase alternating current. The voltage per coil is 5.5 at 1500 R. P. M. and normal field strength, so the 20 coils of one armature, being in series, develop 110 volts. The two armatures differ in phase by 180° and, therefore (by reversing the leads of one), may be connected in series for 220 volts and in parallel for 110 volts, the terminals on the frame being so arranged that either connection may be readily made. Minor changes in voltage are made by a rheostat in the field circuit.

In constructional details the alternator is much the same as the Diehl motor. End brackets G carry the bearing housings which support the liners H and form the oil wells J. Oil gauges K are fitted to show the height of oil in the wells. The end of the bearing is closed by the brass dust cap I, secured against a soft washer by machine screws.

The driving power is a shunt wound motor, mounted on the same shaft as the rotor of the alternator.

Crocker-Wheeler Inductor Alternator.

Fig. 41 shows the Crocker-Wheeler ½ kw. set, the construction being much like that of the Diehl motor generator, except that both motor and generator are enclosed in a single frame.

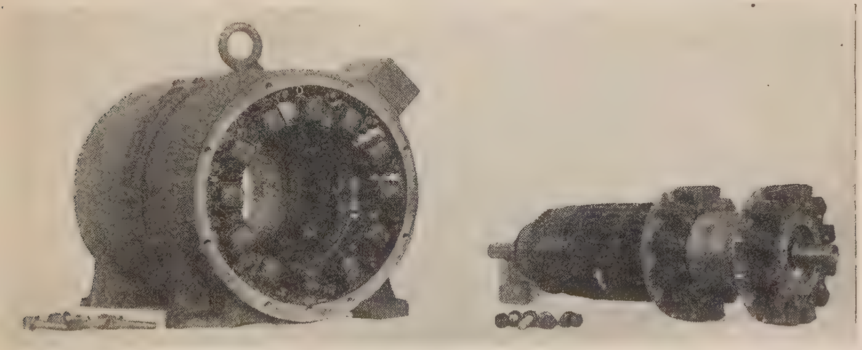


FIG. 41.—Crocker-Wheeler One-Half Kilowatt Radio Motor Generator.

DIRECT CURRENT THREE WIRE GENERATORS.

Three wire generators are installed on all battleships and battle cruisers built later than the *Arizona*. The *Arizona* has two 2-wire and two 3-wire generators. Later battleships each have four 3-wire, 300 kw., 240 volt machines; except those fitted for electric propulsion, in which the number of generators is increased to six, the two extra machines being required to supply current for excitation of the main alternators and to operate electric auxiliaries in the engine room.

Reasons for Adopting the Three Wire Generator.—230 volt motors are more efficient than 120 volt motors, and the power mains are smaller when a given power is transmitted at the higher voltage. Lamps are expensive to make and to operate when the voltage is increased much above 120. Since motors constitute the larger part of the load on battleships and battle cruisers, it has been found advisable to employ the three-wire generator. This supplies suitable voltages both for lamps and for motors, and as the lighting current is relatively small, unbalance in the side circuits never seriously affects the voltage regulation of the neutral.

The allowable drop in motor circuits is 5 per cent of the total voltage; therefore, the E. M. F. at the motors is never below 228 volts and is usually about 230. The drop in lighting circuits is limited to 3 per cent, giving about 117 volts for lamps.

The saving in copper of the motor circuits is large, the cross-section of the conductors being about one-quarter that required for 120 volt motors of the same power. The neutral wire runs only to the switch board, where the lighting circuits are connected alternately from positive to neutral, and from negative to neutral. Thus each lighting circuit is a separate two wire circuit from switch board to lamps, and there is no saving in copper. There is some heat loss in the balance coil and its connections, but the loss of efficiency there is more than balanced by the gain in the motor circuits.

General Electric Co., 300 kw., Three Wire Generator, U. S. S. New Mexico.

The plant consists of four 300 kw., 240 volt, six pole, interpole, compound wound, 1000 R. P. M., three wire generators, gear driven by 5000 R. P. M. turbines.

The generators are built to the same specifications that cover the two wire generator, with certain exceptions made necessary by the alternating current connections. It should be understood that a three wire generator is simply a two wire direct current generator to which is added the alternating current taps and collecting rings; the actual construction is, therefore, not much different.

The General Electric Company three wire generator differs from the 300 kw., two wire generator in the following particulars:

Field Structure.—This differs only in the connections of various fields. As explained in Volume I, it is necessary to divide the field windings of series and commutating coils, having half of each winding in the positive main and half in the negative, in order that the flux may be proportional to the average of the main wire currents. The method of accomplishing this in the General Electric Company generator is shown diagrammatically in Figs. 43 and 44. Starting at the positive brushes, the current flows through

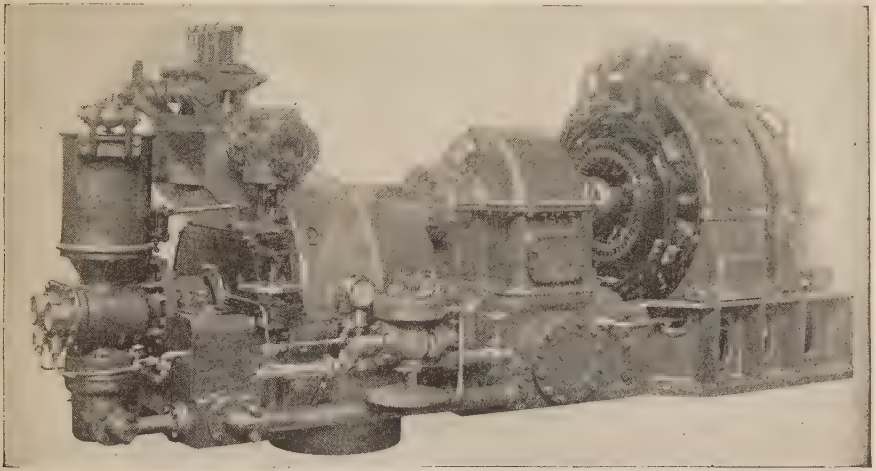


FIG. 42.—300 kw., Three Wire Generator. Gen. Elec. Co.

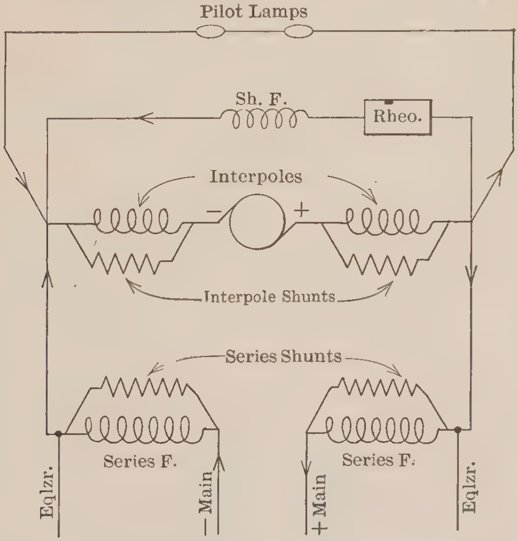

Pilot Lamps
Sh. F.
Rheo.
Interpoles
−
+
Interpole Shunts
Series Shunts
Series F.
Series F.
Eqlzr.
− Main
+ Main
Eqlzr.

FIG. 43.—Field Connections of G. E. Three Wire Generator.

three alternate interpoles to a terminal on the connection board (on the field magnet frame). Here a lead goes to the shunt field, and an equalizer joins the circuit. The current then continues around three alternate main poles, and goes to the positive bus bar on the switch board. Returning in the negative line, the current passes around the three main poles which were omitted from the positive series winding; joins the shunt field circuit and the negative equalizer, and then goes through the three remaining interpole coils. The negative circuit has been omitted from Fig. 44 for clearness; it is identical with the positive circuit shown, the coils being on the poles that are bare in the illustration.

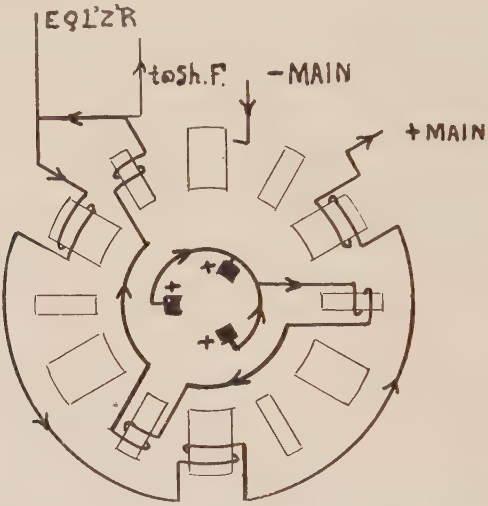


Fig. 44.—Diagram of Series Field Winding, G. E. Three Wire Generator.

The shunt field circuit is connected in the usual way; through the shunt coils of all six main poles in series.

The pilot lamps show when the armature is generating voltage. Two 120 volt lamps are connected in series across the 240 volt armature.

Series and interpole shunts are mounted on the field magnet frame.

Armature.—The armature is lap wound and differs from the 300 kw., two wire generator previously described only in having a single winding and one commutator. The construction is illustrated in Fig. 45.

The Alternating Current Circuit.—This is single phase, and therefore requires two collecting rings. The armature has a parallel winding and six poles; therefore each ring must have three connections to the armature winding. One ring must be connected to three equipotential points in the armature, and the other ring to three equipotential points, 180 electrical degrees away from the first three. Since equalizing circuits connect equipotential points, two of these circuits, which are of greater cross-section than the others, are tapped, and connected to the alternating current collecting rings. One alternating current tap is shown in Fig. 45, connecting to an equalizing ring at A, and leading along the shaft to the right hand collecting ring. The other collecting ring has a similar connection 180 electrical degrees away.

Brushes of copper graphite composition bear on the two collecting rings. The external circuit from alternating current brush to alternating current brush is completed through the balance coil, which is usually called the **stationary compensator.** The compensator is wound on a laminated steel core. The completed coil is contained in a cast iron tank, which is filled with oil. The coil has a lead at each end to the alternating current brushes, and a tap at the center to which the neutral wire is connected.

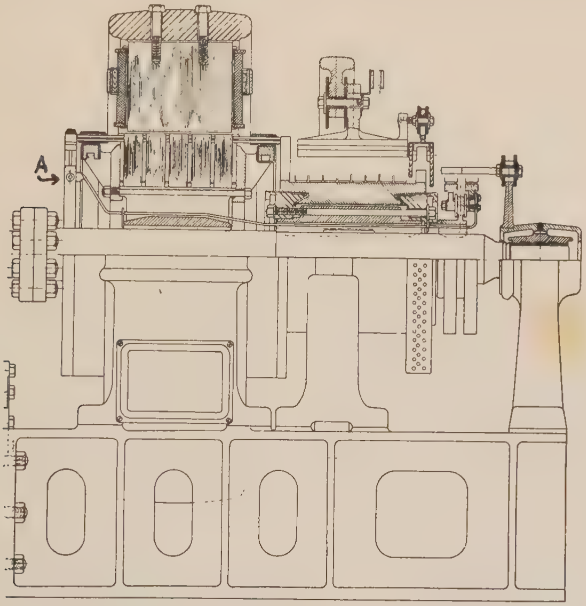


FIG. 45.—Cross-Section of G. E. 300 kw., Three Wire Generator.

Performance.—The generator is flat compounded to within one volt at no load and at full load. That is, if adjusted to 240 volts at no load, the voltage at full load will be not less than 239. Or if adjusted to 240 volts at full load, the voltage at no load will not be greater than 241. The maximum variation at intermediate loads does not exceed four volts either way from 240.

The neutral voltage regulation is 2 per cent of main wire E. M. F. at an unbalance of 540 amperes. This means that if 540 amperes flow in the neutral, and the voltage across the direct current brushes is 240, the variation in voltage of the side circuits will not exceed 2 per cent of 240, or 4.8 volts. Thus the maximum voltage between neutral and one outside wire will not be greater than 122.4, and the minimum not less than 117.6 volts. It should be understood that these are voltages at the generator; the line RI drops cause a reduction in the external circuits.

Westinghouse 300 kw., Three Wire Generator, U. S. S. Arizona.

The description of the General Electric Company's installation on the *New Mexico* applies in a general way to the Westinghouse generator illustrated in Fig. 46. The Westinghouse machine has a two phase compensator; the four collecting rings necessary for the alternating current circuits are shown to the left of the commutator in Fig. 46. The alternating current brushes are of copper and are supported from the same brush rigging that carries the direct current brushes.

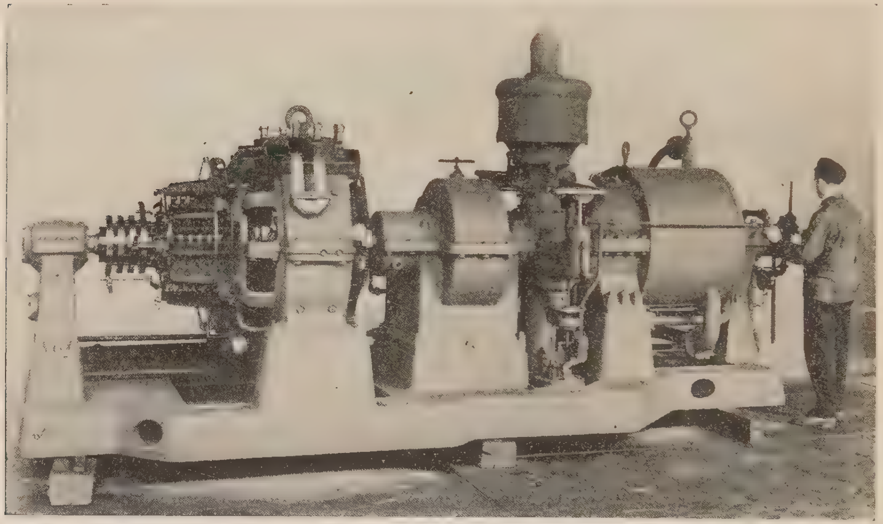


FIG. 46.—300 kw., Three Wire Generator, Westinghouse Elec. and Mfg. Co.

CHAPTER III.

SERVICE MOTORS.

On board modern naval vessels, nearly all auxiliary power is furnished by electric motors. Electric power is used for turret turning, gun elevating, ammunition hoists of all kinds, boat cranes, deck winches, anchor windlasses, coal hoists, ash hoists, air compressors, watertight doors and hatches, workshop machines, ventilating fans, blowers, galley and laundry machines, etc.

In selecting a motor for any one of these purposes, consideration is given to the following characteristics: *Designed voltage, mechanical construction, field winding, use of interpoles, control system.*

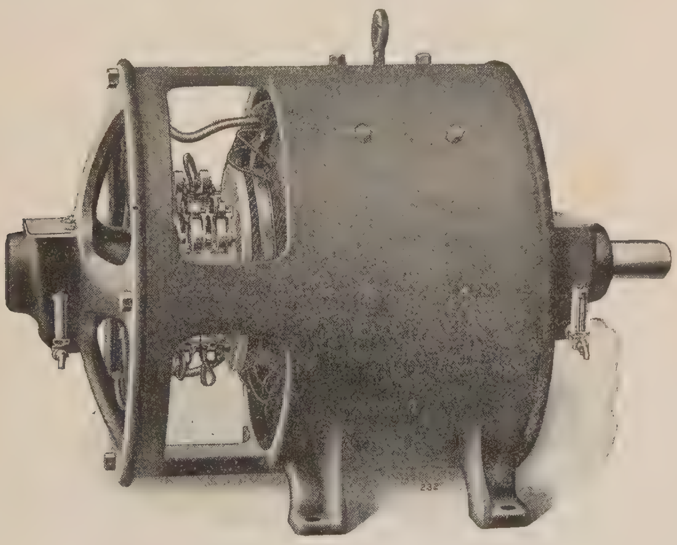


Fig. 47.—Diehl Open Motor.

The bearing which each of these features has on the suitability of a motor for a particular purpose is discussed in a general way in the paragraphs that follow, and examples of actual installations are given in later chapters.

Designed Voltage.—Motors are wound for the voltage delivered by the generators of the ship, less the allowed line drop. A few volts more or less in the designed voltage makes little difference with the direct-current motors used on board ship, and they are usually designed for 80 volts on old ships, 120 volts on ships with 125-volt generators, and 230 volts for ships using the 240-volt, three-wire system.

Mechanical Construction.—The various details of construction, such as method of securing the poles, supporting the bearings and so forth, are matters of design and have small influence on the suitability of a motor for a given purpose. The protection given to the parts of the motor is, however, always considered and motors are classified in this respect as **open, semi-enclosed** and **enclosed.**

Open motors have no covering over the commutator and brush rigging and both ends are open. This type is illustrated in Fig. 47.

The **semi-enclosed** type is illustrated in Fig. 48 and has ventilated coverings to protect the commutator and brush rigging and both ends from injury by solid objects.

The **enclosed** type (Fig. 49) has metal coverings for protection against solid objects, dust and water. If the hand hole plates and stuffing boxes are tight enough to keep the motor dry when exposed to the wash of waves or water from a hose, the motor is called "enclosed watertight." If the coverings are merely designed to keep out dust, the motor is called "enclosed non-watertight."

Field Winding.—Series, shunt, compound and differential motors are used, the class of work for which each is best suited being in general as follows:

The Series Motor.—In this type the field varies as the armature current up to the point of saturation. The torque varies as the field times armature current; therefore, the torque varies as the square of the armature current. A motor is usually designed to carry 100 per cent overload for short intervals without excessive heating, and at that overload the series motor exerts a torque four times the designed normal, neglecting the effects of armature reactions and saturation, which may be considerable. The motor may, of course, be designed for more or less than 100 per cent overload, giving a greater or less maximum torque. The electrical connections are so arranged that, in starting, the armature current will reach the allowed maximum if the load demands it, and so the torque may reach about four times normal when the armature is just beginning to turn over. Compared to other direct current motors, this turning effort is large, so the motor is said to have a large starting torque. Since increase in mechanical load demands increase in current and this in turn strengthens the field, the series motor slows down on increase of load and speeds up when the load is decreased. At very light load the speed becomes excessively great and may cause damage from centrifugal strains. Since the field strength increases with the armature current up to the saturation point, there is but little tendency toward field distortion and the series motor commutates well under wide change in load. Speed is usually controlled by the wasteful but effective armature rheostat method, and since this involves no change in the relative strengths of main and armature fields,

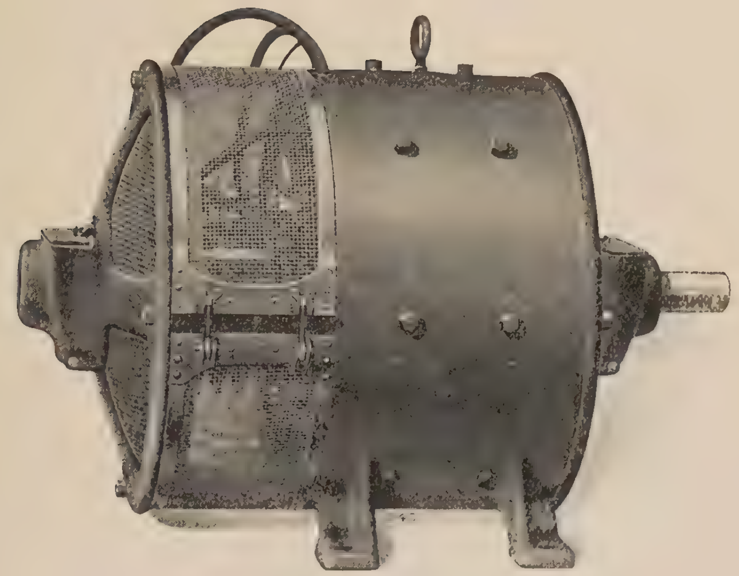


FIG. 48.—Diehl Semi-Enclosed Motor.

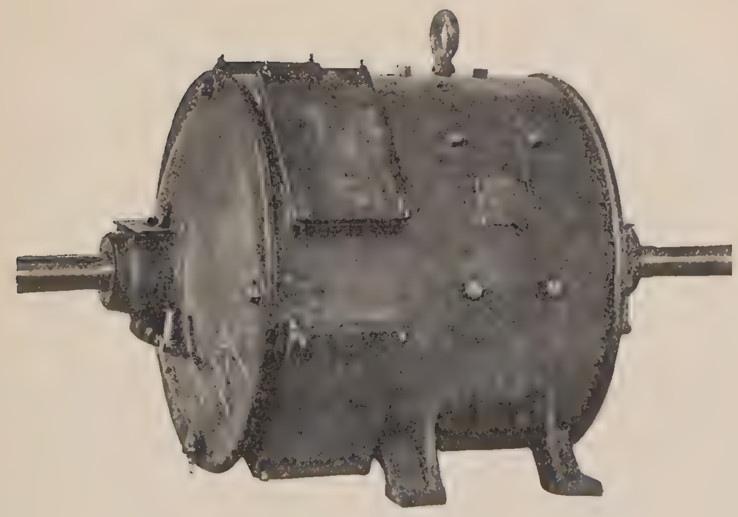


FIG. 49.—Diehl Enclosed Watertight Motor.

the series motor can handle a given torque through a wide range in speed without commutation troubles.

To sum up the characteristics of the series motor: It can handle torques varying from considerably less than normal to about four times normal without exceeding double the normal armature current. Its speed automatically varies as the load changes. Its speed with a given mechanical load may be accurately controlled through a wide range. Under very light load it will race.

It is therefore used for such purposes as boat crane hoisting and revolving, where fine speed control is essential, where good speed regulation is not essential, and where the load varies widely, but is never excessively small.

The Shunt Motor.—Since the field current is practically independent of the load, the torque increases as the armature current. At 100 per cent overload the torque would be twice normal, were it not for the demagnetizing effect of the armature field, which somewhat lessens the maximum turning effort. The starting torque is the same as the maximum, and is small compared to other direct-current motors—about half that of a series motor of the same rating. Since increase in armature current tends to weaken the main field, the change in speed with change in load is small. The field excitation being constant, the speed will not greatly exceed normal with very light load and the shunt motor can be run on only the stray loss torque without danger. Since the armature field changes with change of load, while the main field is constant, there is considerable flux distortion and the shunt motor does not commutate well under wide changes in load unless commutating poles are used. Speed is usually controlled by the economical field rheostat method, and, since this involves a weakening of the main field and, indirectly, a strengthening of the armature field, or *vice versa,* the speed control is limited by brush sparking. The speed range may, of course, be increased by the use of commutating poles, but is never as large as that of the series motor. It should be noted that the danger point in the shunt motor is at excessive overload, where fuses and circuit breakers afford protection and, consequently, it requires less careful attention than the series machine in which the danger point is at excessive underload, where circuit breakers will not prevent damage.

To sum up the characteristics of the shunt motor: It can handle torques from almost nothing to less than twice normal without exceeding double the normal current. Its speed varies little with change in load. Its speed with a given mechanical load can be varied, but not nearly so much as with the series motor. It will not race if unloaded.

It is therefore used for such purposes as blowers, where great range of speed control is not essential, where good speed regulation is desirable, and where the load never greatly exceeds normal, but may become very small.

The Series and the Shunt Motor Compared.—The underlying principles of these two motors may be compared by considering the advantages of each for a certain service. For example, a boat crane is designed to hoist a certain boat requiring a certain torque at the motor, which may be handled by either a shunt or a series motor designed to take, say, 100 amperes. The weight of the boat produces the full load torque for which the motor is designed, but it has been found that this torque may be increased momentarily as much as four times by rolling of the ship or other causes. In such case, a series motor would take 200 amperes and slow down considerably; while a shunt motor would not slow much, but would take 400 amperes. As a matter of fact, the shunt motor we are considering would not do, because it is practically impossible to design one to carry four times the normal load current, 100 per cent overload being about the limit. So the shunt motor would have to have a designed full load torque twice as great as a series motor for this service, and would be larger and would operate less efficiently under normal conditions. Furthermore, a shunt motor starting a heavy load accelerates more quickly than a series motor, because of its tendency to run at a constant speed regardless of the load, and this causes undesirable jerking of the crane whip and large fluctuations of current. Hence the series motor is used for boat cranes, because it is smaller, uses less current on overload, starts the load gently, and does not require the generators to handle heavy current fluctuations.

Now consider a chain ammunition hoist, which runs steadily, sometimes empty and sometimes loaded with ammunition. It may run indefinitely in the loaded condition, so that is the normal full load of the motor. This full load could be carried with equal economy by a series or a shunt motor taking, say, 100 amperes. The hoist is never much overloaded and is started when empty, so that the conditions when accelerating under load, and when overloaded need not be considered. When the hoist is empty the torque is considerably reduced, say, to one-quarter normal. Then a series motor would speed up considerably and take 50 amperes, while a shunt motor would speed up but little and take 25 amperes. Hence the shunt motor is used for chain ammunition hoists because it takes less current than the series machine on underload, and runs at a nearly constant speed whether loaded or not.

In general, then, any motor must be designed for a full load equal to the greatest load that must be handled for long periods. If temporary variations from full load are for the most part increases, a motor with series characteristics is the better; while, if the variations are decreases, the shunt characteristics are the better. If the variations are very small, either motor will be satisfactory, the efficiency of the controlling apparatus being then the determining factor. Shunt motors being easily controlled by shunt field rheostats are therefore used for constant load work, except when the power is very small, as in desk fans and small blowers where series motors with armature rheostat control are used; this control causing but little heat loss with the small current required, and the construction of the series machine being simpler and cheaper than the shunt-wound type.

The Saturated Field Shunt Motor.—The ordinary shunt motor is always operated with its field below saturation and is, therefore, very sensitive to armature reactions; to which is due its nearly constant speed and small starting torque. A distinct type, in which the field is saturated, has a limited use. The characteristics of this machine are a more widely varying speed than in the ordinary shunt-wound motor, and a greater increase in torque with increase of current, both due to the fact that the armature reactions have small effect on the saturated field. An example of the use of this type is found in the jacking motors for the *Arkansas*' main turbines, a service which might be expected to call for compound winding.

The Differential Motor is used very little. Its speed regulation is better than a non-interpole shunt motor because the series winding weakens the field on increase of load and so tends to keep the speed constant. It was formerly used for the motors of radio motor generators where constant speed under varying loads is needed. The shunt motor can be designed with practically as good speed regulation as the differential machine and has replaced it for radio and other constant speed work.

The Compound Motor has characteristics intermediate between those of the shunt and series machines. It formerly had a rather limited use, and on old and fairly modern ships is employed only for such purposes as deck winches, where the series turns supply the large torque necessary to start the load and the shunt winding prevents excessive speed in case the load is suddenly lost, as might happen by the breaking of a hawser. Its use is increasing, however, and on the latest ships it is employed to some extent where shunt and series machines were formerly used. A very few series turns give practically the same characteristics as the shunt motor and improve the commutation, while heavy compounding (about 50 per cent series and 50 per cent shunt ampere turns) gives practically the same characteristics as the series motor but improves the speed regulation, eliminating the danger of racing.

The speed and torque characteristics of motors as discussed above are slightly altered when interpoles are used, but the effect is negligible except in the case of shunt machines, which are treated further under the heading "Stabilizing Windings," on page 41.

Use of Interpoles to Improve Commutation.—Interpoles are used where the service is such that non-interpole motors would spark at the brushes. It may be said that the function of commutating poles is to keep the axis of commutation fixed. They are, therefore, used on motors where there is a tendency for the commutating axis to move, which occurs when there is a relative change in the strengths of main and armature fields. The following summarizes the use of interpole motors:

Motors Operating Under Varying Load.—Motors in which the field strength does not vary as the armature current (shunt and compound machines), when used with varying loads, have a relative change in strengths of main and armature fields and require commutating poles.

Variable Speed Shunt Motors.—In this type speed is increased by weakening the field. In a well-designed slow-speed shunt motor without interpoles, about 30 per cent. increase above normal speed can be obtained without sparking. When the service demands greater speed variation than this, commutating poles are fitted.

High-Speed Motors.—The rapidity of reversal of current in the commutated coils of very high-speed motors, and the consequent high reactance voltage, will cause brush sparking if the brush setting is not very exact. The very slight shifts in the commutating axis under small changes in load, which would have no effect in a slow-speed motor, will cause sparking in the faster type, and interpoles are, therefore, usually used.

Reversible Motors.—Interpole motors are usually used when the direction of rotation must be reversed, to do away with the necessity for shifting brushes.

Use of Interpoles to Economize in Field Ampere Turns.—To prevent excessive field distortion with non-interpole motors, the magnetomotive force of the main field must be so much greater than the M. M. F. of the armature field that the demagnetizing component will have no great effect on the total flux. For this reason the main field must have more ampere turns than would otherwise be necessary, and the reluctance of the magnetic circuit must be correspondingly increased by using wide air-gaps. With interpoles, the demagnetizing component is suppressed by placing the brushes in the neutral axis, so the reluctance of the magnetic circuit may be decreased as much as mechanical considerations allow, with consequent saving in field ampere turns. For this reason some manufacturers use interpoles on nearly all motors, even though the conditions of commutation do not demand a commutating flux.

Stabilizing Windings.—The effect of interpoles is only local; they supply a commutating flux that reverses the current in the coils under the brushes, but they have very little effect on the rest of the field, except that produced by the flux that leaks from them to the main poles without threading the armature. One indirect result of interpoles is the suppression of the demagnetizing component of the armature field, by placing the brushes in the neutral axis. The nearly constant speed of the shunt motor depends on the demagnetizing effect of armature reactions, this effect being partly due to the crowding of the flux to one tip of each main pole, which becomes partly saturated, thus weakening the field; and partly to the opposing magnetomotive force set up by the demagnetizing component. Since the latter does not exist in an interpole machine with no brush lead, it might be supposed that the speed would not be so constant as in the simple shunt motor. It happens, however, that the leakage flux from the interpoles has the same effect as the demagnetizing component would have, if it existed. In Fig. 50, the full lines represent the magnetomotive force of the main poles and the dotted lines represent the interpole M. M. F. along the paths of the leakage flux. Of course the M. M. F. of the interpoles also tends to send a flux through the armature, but the effect of this is cancelled by the armature M. M. F. and the reactive voltage in the commutated coils, and need not be considered. The two M. M. F.'s shown in the figure are in parallel and in the same direction. The main pole M. M. F. does not change, but the interpole M. M. F. increases with increase in load. When this occurs the leakage flux also increases and crowds out part of the main flux in the field magnet frame, and so weakens the field. The analogy of this case is seen in the action of two cells connected in parallel to an external circuit. If the voltage of the one (corresponding to the M. M. F. of the interpole) is increased while the other is not changed, more current will flow in the external circuit (corresponding to the field magnet frame), but in the second cell the current (corresponding to the main flux) will decrease. This action is more pronounced in the magnetic circuit than in the electric circuit because resistance is a constant quantity, but reluctance increases with flux density.

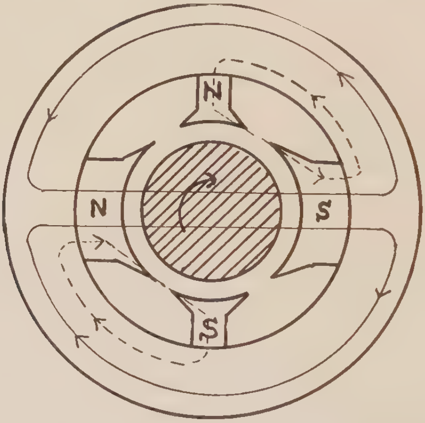


FIG. 50.—Magnetic Circuits of Interpole Motor.

The extent of this demagnetizing action depends on the design of the motor, since the closer the poles the greater the leakage coefficient. In some motors it is about the same as the demagnetizing component would be if interpoles were not used, and the speed and torque characteristics are about the same as those of a similar non-interpole motor. With closer pole spacing, the effect is more pronounced but is not of great importance except in shunt motors. In the shunt machine very close pole spacing may give a rising speed characteristic; that is, the speed will increase with load. This is an unstable condition because an increase of load causes increase in speed, this further increases the load by the amount of torque required to accelerate the armature, this in itself produces a further tendency to increase the speed, and so on, until the motor fails electrically or mechanically. The rising speed characteristic is corrected by winding the main poles with a few series turns to help the shunt coils. This series winding is called a **stabilizing winding** because it corrects the unstable speed characteristic, but in construction the poles differ in no way from those of a lightly compounded motor. The distinction is, that in a compound motor the series turns are used to compensate for the demagnetizing effect of the armature field and the armature RI drop, while in a stabilized shunt motor they compensate for the demagnetizing effect of the interpole leakage flux. As a matter of fact there is little distinction made in practice, both types being usually known as compound motors; but it should be understood that the recent rather extensive use of compound motors in place of shunt motors is partly to secure this stabilizing effect; and in very compact machines, such as the main motors of submarines, compounding is resorted to for this purpose alone.

Control Systems.—The type of speed control which is the best adapted for the kind of motor selected is usually used. Shunt and compound motors are easily and economically controlled by field rheostats, while series motors are usually controlled by rheostats in the line, the effect of increasing this resistance being to lower the terminal E. M. F. of the machine. A great many devices for varying the controlling resistance are in use, the more important ones being described in later chapters.

THE CONSTRUCTION OF THE MOTOR.

The principles of motor construction are covered in Chapter I, but in order to illustrate the difference between the dynamo used as a motor and the dynamo used as a generator, the following description of one type of motor is given in detail. The differences in details of construction between the type described and those of other manufacturers are many, but are easily recognized by inspection of the actual machines.

Sturtevant Blower Motor.

General.—Eight-pole, shunt-wound, enclosed watertight motor, direct connected to blower shaft. The motor has no bed plate, the bearings being supported by end bonnets secured to the field magnet frame. The frame is bolted to the blower casing.

Magnet Frame.—The magnet frame consists either of a cast-iron ring, which is machined on the two faces and bored out on the internal surface to receive the field cores, or of a wrought iron or cast steel ring, machined all over both inside and out. The magnet frame is indicated in Fig. 52 by (1), and to the inner machined surface of which are secured by the bolts (27), field cores (4).

Poles.—The poles consist of Norway iron field cores with cast-iron pole pieces attached.

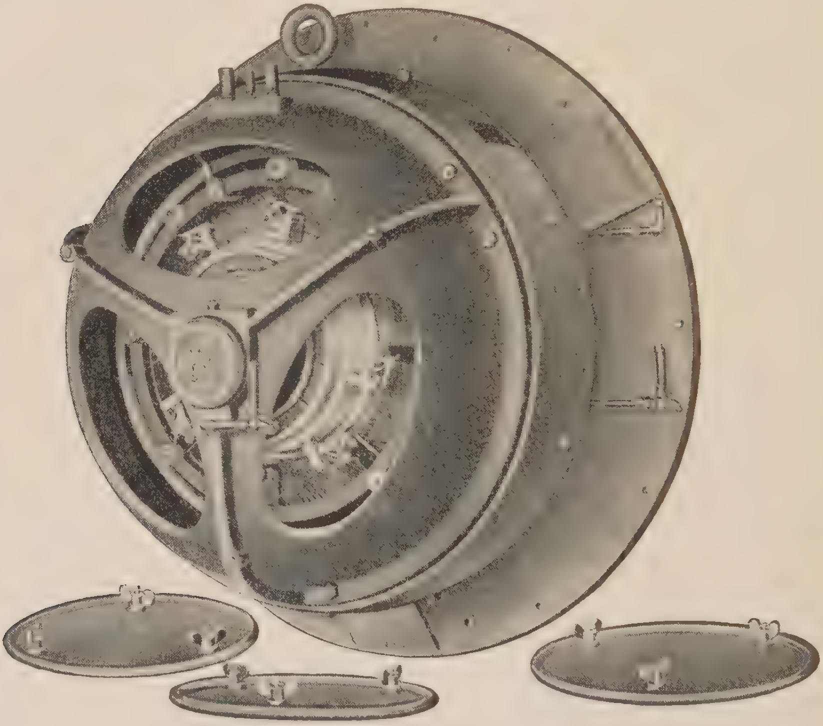
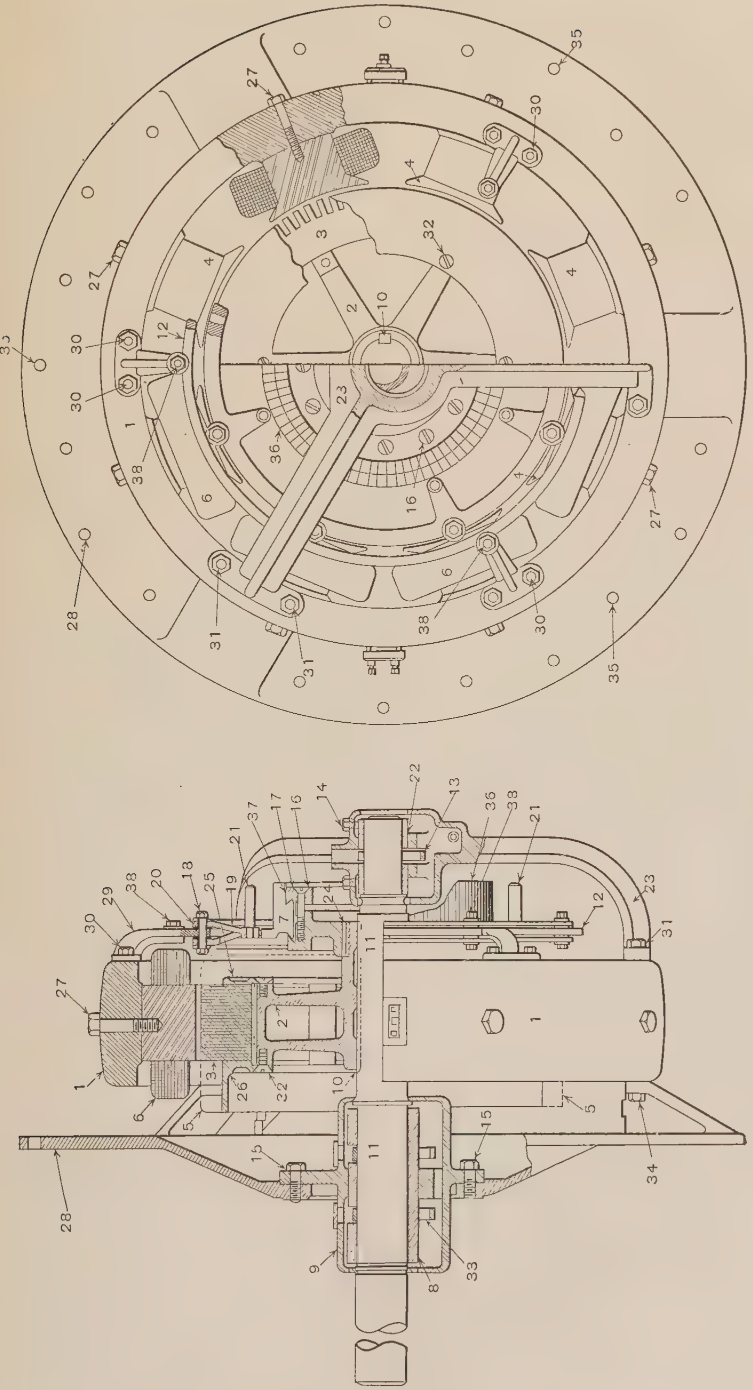


FIG. 51.—Sturtevant Blower Motor.

Field Coils.—The field cores (4) are each encircled by the field coil (6), which consists of double cotton-covered magnet wire of highest conductivity, machine wound upon a form, after which it is thoroughly insulated by the following process:

1. Baked two hours at 150° F. to exclude all moisture.
2. Given two layers of heavy cotton tape.
3. Saturated with an insulating compound of highest possible moisture resisting qualities.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26
32
10
6
5
5
11
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15
34
28
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8
33

FIG. 52.—Sturtevant Blower Motor.

4. Baked five hours at 150° F.
5. Given two layers oiled rope tape.
6. Given two layers of finishing tape.
7. Finished with a heavy coat of quick-drying, black, oil, water- and acid-proof insulating varnish.

After this treatment, and being placed on the pole pieces, a break down test of 2500 volts is applied for one minute. These field coils are supplied with flexible leads, which are connected as hereinafter described.

Armature.—The armature (5) consists of a core (3) of laminated punchings of low carbon steel clamped between two cast-iron flanges (25 and 26), secured to the cast-iron spider (2) by means of the screws (32). On account of the large diameter and open construction of this armature, together with the extremely narrow construction of the core, ventilating discs through the core are not necessary, perfect ventilation being attained by the freedom with which the air may circulate through and about the entire armature.

The armature is of the drum type and the coils are form wound. Before being placed upon the core all coils are thoroughly insulated, additional insulation being placed in the slots as an extra precaution.

Commutator.—The commutator (36) consists of pure drop-forged or drawn-copper segments (7) clamped in a shell (17) by means of the screws (16) and thoroughly insulated by the micanite rings (37). Pure amber mica only is used between the segments.

This commutator when completed is mounted directly upon a projection from the armature spider, being held in place by a key (24). The entire assembled armature is then forced upon the shaft of crucible steel (11), to which it is firmly secured by the key (10), upon the top of which is a set screw.

Bearings.—The bearings are of the ring-oiling type and consist of two composition sleeves (8 and 22), the rear bearing being of self-aligning construction and having two oil rings (33), while the front sleeve (22) has only one ring (13). The front sleeve (22) is held in place by two screw pins (14), and the back sleeve is held in the box (9) by screw pins, which are not shown upon the plate. The front bearing sleeve is supported in an end bonnet (23), which bonnet is firmly secured to the magnet ring (1) by the six cap screws (31). The back-bearing sleeve (8), as above stated, is supported in a cast-iron box or shell (9), which is secured to the cast-iron fan bracket or plate (28) by cap screws (15). This cast-iron fan bracket (28) supports the entire motor by being secured to the field frame by the cap screws (34), and the entire machine is secured to the side of the fan by through bolts which pass through the holes (35).

Brush Rigging.—The brush rigging is of special construction and consists of two stud rings (19) to which are riveted the brush-holder studs (21); and the rocker ring (12) to which the stud rings are secured by through bolts (18). The rocker ring is supported by the brackets (29). This brush rigging is so designed that all the studs of like polarity are attached directly to one stud ring, and all studs of opposite polarity are attached directly to the other. These two stud rings (19) are thoroughly insulated from each other and from the rocker ring (12) by the hard-rubber insulating washers and bushings (20). By loosening the small screws (38) this entire brush rigging is free to revolve around its axis.

Reliance Motors.

The Reliance motor is a special type used to some extent on board ship to drive machine tools.

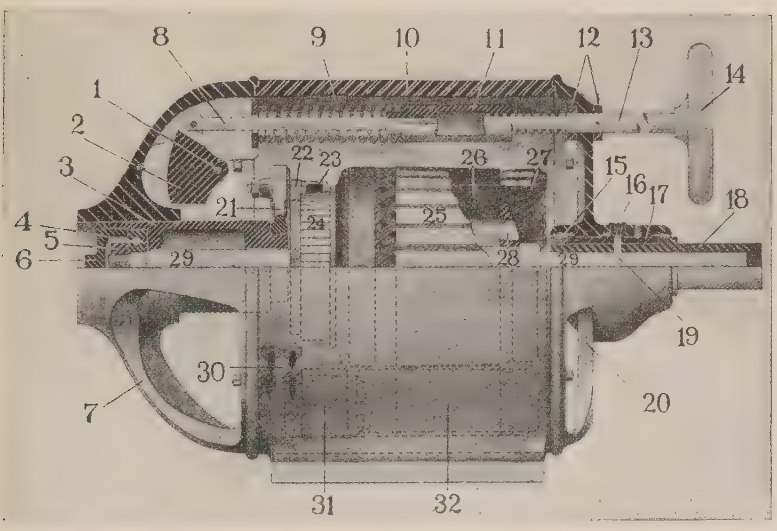


FIG. 53.—Cross-Section, Showing Principal Parts. Reliance Adjustable Speed Motor.

1. Lever Fulcrum Pin.
2. Lever.
3. Sliding Thrust Bearing Box.
4. Ball Bearing.
5. Armature Shaft End Nut.
6. Cap.
7. Commutator End Yoke.
8. Lever Rod.
9. Compression Spring.
10. Steel Frame.
11. Speed Adjustment Nut.
12. Thrust Collars and Pins.
13. Hand Wheel Rod.
14. Hand Wheel.
15. Sleeve Nut.
16. Oil Well Cover.
17. Bearing Bushing.
18. Sleeve.
19. Oil Ring.
20. Pinion End Yoke.
21. Rocker Arm.
22. Brush Stud.
23. Brush.
24. Commutator.
25. Armature.
26. Armature Laminations.
27. Armature Coils.
28. Armature End Plate.
29. Armature Shaft.
30. Leads.
31. Axial Position of Commutating Pole.
32. Axial Position of Main Field Pole.
33. Slide Rail Screws.
34. End Yoke Cap Screws.
35. Slide Rails.
36. Commutating Coil.
37. Commutating Pole.
38. Main Field Pole.
39. Main Field Coil.

These motors are built for variable speed upon the principle of weakening the field by increasing the length of air-gap in the magnetic circuit.

The details of construction are shown in the cross-section, Fig. 53, which clearly indicates the special construction necessary in order to obtain the shifting of the motor armature. At the driving end the armature shaft **29** slides back and forth on a feather key inside the sleeve **18**. This sleeve revolves in a ring oiling bearing bushing **17**. A shoulder on the sleeve and the circular nut **15**, each having a bearing against one of the end faces of the bushing **17**, prevent any lateral movement of the sleeve as the armature shaft slides back and forth. As the pulley, pinion or coupling is mounted directly on sleeve **18**, the motion of the armature shaft inside this sleeve in no way affects the method of drive.

At the commutator end, the armature shaft **29** is carried by a combination thrust and radial ball bearing **4** whose inner race revolves with the shaft and is clamped between a shoulder on the shaft and the nut **5**. The outer non-revolving race is similarly clamped between a shoulder of the sliding thrust bearing box **3** and the cap **6**. Any means, therefore, of sliding the box **3** back and forth will in turn cause a corresponding lateral movement to the armature, the pull being imparted from the non-revolving to the revolving parts through the ball bearing **4**. This ball bearing, although of the radial type, will carry a thrust load equal to a large percentage of its guaranteed radial capacity and has ample leeway to take care of any thrust load to which it is subjected in shifting the armature.

In the standard motor the shifting of box **3** is accomplished by means of a lever **2**, which straddles the box with lugs engaging in recesses on each side. This lever pivots on a steel fulcrum pin carried between two ears, projecting from the under side of one arm of the commutator end yoke **7**. The two collars **12** prevent any lateral movement to the hand-wheel rod **13**, which, on being revolved one way or the other, pulls the upper end of the lever back and forth by means of the lever rod **8** and speed adjustment nut **11**. Turning the hand wheel **14**, therefore, gives a gradual lateral movement to the armature.

The compression spring **9** is used to balance the magnetic pull on the armature, thus relieving the collars **12** of all thrust and causing the hand wheel to turn with great ease.

In its normal low speed position, the armature revolves in the position shown in the cut, that is, directly under the main field poles **32**, which are shunt wound. The diameter of the armature core at the end towards the commutator is slightly greater than at the opposite end, giving a slight taper or cone shape to the armature. The inner faces of the main poles are given a corresponding taper so that, in the air space between the surface of the armature and the inner face of any main pole, the distance between the two surfaces measured radially, that is, the air-gap length, is the same at all points, but increases gradually as the armature is shifted laterally away from the main poles. It is also evident that as the air-gap length increases the air-gap area, or surface of the armature directly under the face of the main poles, decreases. Both changes tend to increase the reluctance of the magnetic circuit, or when the armature is shifted in the opposite direction towards the main poles, cause a decrease in the magnetic reluctance.

As the strength of the shunt field coils energizing the magnetic circuit is kept constant, any change in the magnetic reluctance causes a corresponding change in the strength of the field within which the armature rotates and this in turn causes a change in speed. Hence as the hand wheel **14** is turned in one direction, causing the armature to gradually shift laterally away from the main poles, there is a gradual and continuous decrease in the strength of the magnetic field and a corresponding gradual and continuous increase in the speed. Similarly turning the hand wheel in the opposite direction causes a gradual and continuous decrease in speed.

Laterally displaced from the main poles are the two commutating poles **31**. The energizing coils on these are in series with the armature winding, giving a commutating effect in proportion to the current or load carried. The commutating effect is also in proportion to the weakening of the magnetic field, for the armature is brought more and more under the influence of these poles as it is shifted laterally away from the main poles. As a result satisfactory commutation is obtained at all speeds in either direction, even under heavy overloads.

A contributing and very important factor to good commutation is the fact that with a given current in the armature and a given distorting effect there is practically no greater field distortion at high speed with weak magnetic field than at low speed with full magnetic field. There are two reasons for this, first, with any decrease in the strength in the magnetic field the air-gap length increases, and, second, the area of the iron through which the magnetic field passes decreases, keeping the degree of saturation practically constant. Both effects tend to prevent the distortion of the main magnetic field under a given armature reaction.

The absence of field distortion combined with proper commutating poles makes it possible to obtain ranges in speed as great as one-to-ten. In the ordinary machine tool drive, however, it is seldom necessary to use more than one-to-six range in the motor, as where wider ranges are desired it is usually more economical to install gear changes, using motors of medium range.

The armature core is made of thin punchings of specially selected sheet steel thoroughly annealed. The armature winding is a standard type of wave winding, the coils being of double cotton-covered copper wire form wound and taped. Each coil is made of three independent sections which are connected in series through the commutator bars. The slot insulation consists of cells made up of three thicknesses of specially treated tough paper with heavy strips of fiber between coils and at the top of each slot.

All field and armature windings are heated in a drying oven and are then impregnated both with an oil and waterproof insulating compound. After the final impregnation they are thoroughly baked for 24 hours.

The speed control being accomplished by the mechanical shifting of the motor armature, the wiring required for installation and the type of starting equipment necessary are exactly the same as those for any direct-current constant-speed motor. No electrical resistance controller, in the ordinary sense of the word, is required, but merely some rugged type of starting equipment.

A type of speed indicator is furnished with Reliance Adjustable Speed Motors for machine tool drive by which it is possible to set, instantly, the speed of the motor so as to give any desired cutting speed at the cutting tool. This speed indicator automatically takes into account the speed of the motor, the ratio of the drive, the size of the work and the cutting speed desired.

The characteristics and advantages of the Reliance Adjustable Speed Motor for machine tool drive are briefly as follows:

1. No electrical controller is required.
2. An infinite number of speeds over wide speed ranges.
3. Constant horsepower output at all speeds.
4. Heavy overload capacity at all speeds.
5. Automatic starting equipment can be used.
6. Light weight and compactness.
7. The motor is reversible and will run with like results in either direction without shifting the brushes.

CHAPTER IV.

APPARATUS FOR MOTOR CONTROL SYSTEMS.

The various pieces of apparatus which make up the devices employed in starting and in controlling the speed of motors may be classified as *rheostats, circuit breakers, fuses, switches* and *brakes.*

RHEOSTATS.

A rheostat is a resistance device, usually adjustable, placed in a circuit for the purpose of regulating the current in that circuit. The resistive conductors are known as resistances, resistance units, or resistors. They are insulated in various ways and are mounted in a frame. A rheostat is usually a combination of resistance units and a switch of some kind, by means of which all or any part of the total resistance may be cut into the circuit. The general requirements for the material of the resistive conductors are low temperature coefficient, and ability to stand without damage high temperatures and exposure to salt air and salt water. German silver and similar alloys most nearly fulfill these requirements. Cast iron, which is cheap and can stand hard service, is used to some extent where exact resistance values are not essential; its disadvantages being an appreciable change in resistance with change in temperature, liability to rust, and liability to fracture under the shock of gun-fire.

The various forms of resistance units have distinguishing names, by which the rheostats in which they are incorporated are known. Examples follow:

Pressed Ribbon (PR) Resistance.—This is used for heavy currents. The resistance units are composed of German silver ribbon doubled back and forth upon itself, asbestos insulation being used between layers. The completed rheostat is composed of a number of such units mounted in a cast-iron frame.

Pressed Card (PC) Resistance.—Used where high resistance and small current capacity are required. German silver is wound on a hollow asbestos tube which is then pressed into a V-shaped card. A number of these cards are mounted in an insulated iron frame, forming one resistance unit.

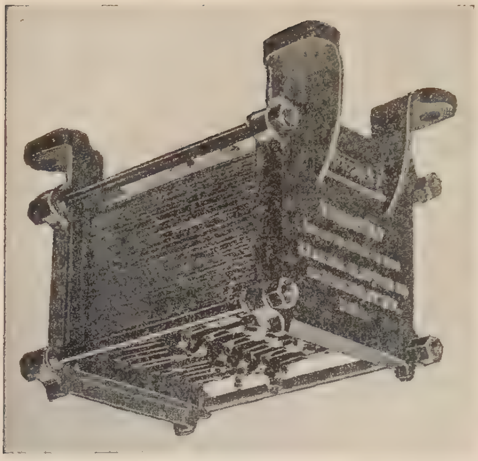


FIG. 54.—Pressed Ribbon (PR) Rheostat. Gen. Elec. Co.

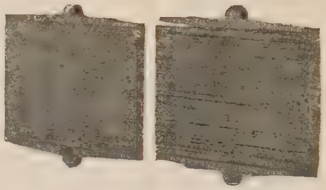
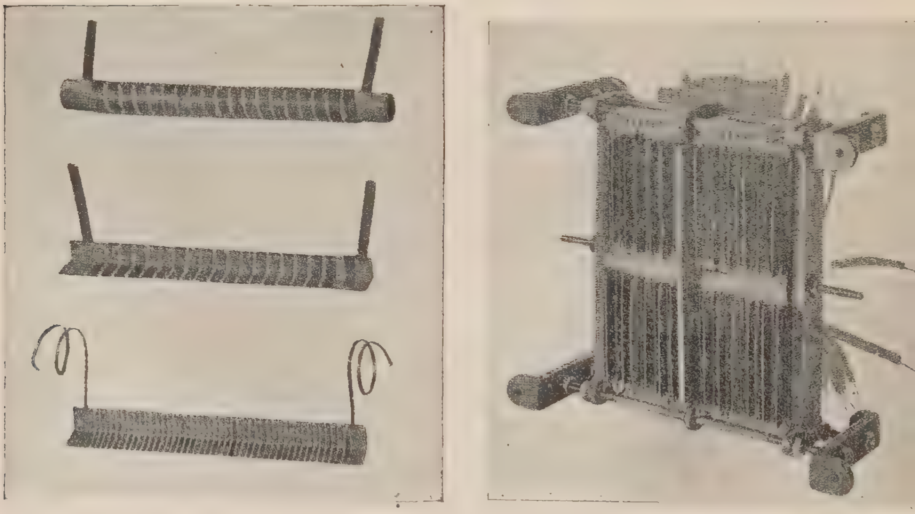


FIG. 55.—PR Resistance Units.



Steps in Construction of a Card. Cards Assembled in Iron Frame.

FIG. 56.—Pressed Card (PC) Resistance. Gen. Elec. Co.

Enclosed Card (EC) Resistance.—Used where high resistance and small current capacity are required. This is the same as the pressed card type except that the card is pressed flat and enclosed in an asbestos-lined sheet-metal casing.

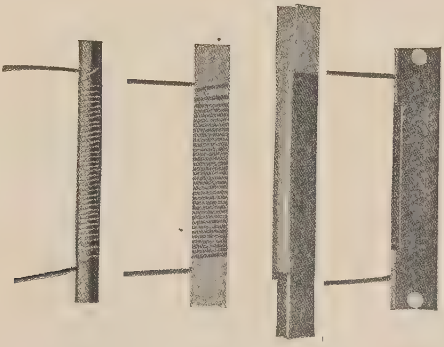


FIG. 57.—Enclosed Card Resistance.
Gen. Elec. Co.

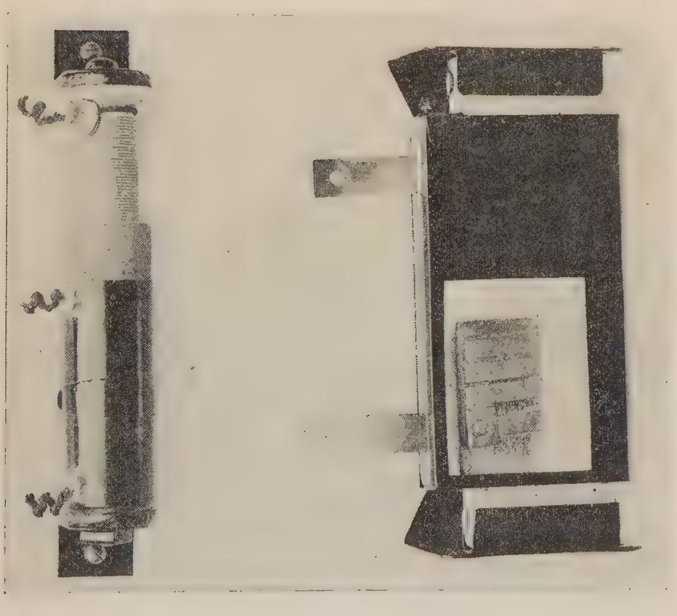


FIG. 58.—Structural View of Types R and N Resistance Units.
Cutler-Hammer Elec. Co.

R and N Resistances.—Used where high resistance and small current capacity are required. Type R is a porcelain cylinder wrapped with wire, and type N is a rectangular block of soapstone wrapped with ribbon or wire. In both types the completed unit is enclosed in a sheet-iron case packed with cement. A unit may have more than two leads. Type R usually has three as shown in the figure, so that only half the resistance may be used if desired, or the two halves may be used in parallel. Type N is furnished with any number of taps from two to eight.

Edgewise Wound (ES) Resistance.—Used where very high temperatures are generated in the resistance. Resistance ribbon is wound on edge on a supporting tube from which it is insulated, ordinarily by asbestos. After winding, the tube is dipped in a silicate which, when hardened, separates the turns and covers the outside of the resistance.

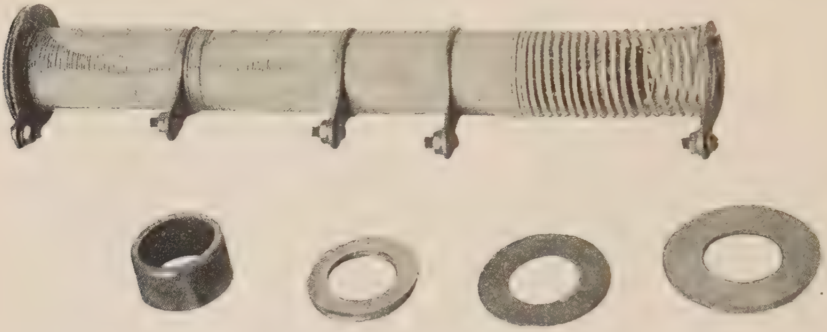


FIG. 59.—Edgewise Wound Resistance Unit. Gen. Elec. Co.

FM Resistance.—Used where very high temperatures are generated in the resistance and where the current is not great. It consists of an asbestos tube supported at the ends by porcelain bushings. The resistance material is wound on the tube, which is then coated with a silicate. This unit will stand a very high temperature without injury and has a large radiating

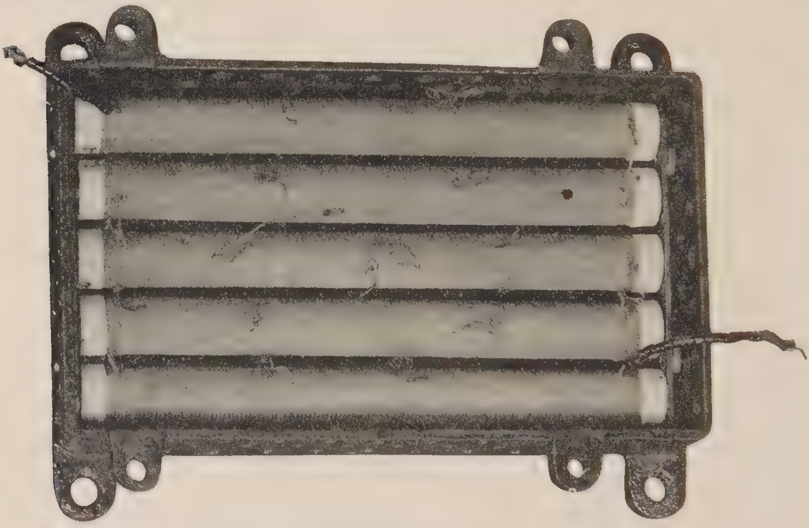


FIG. 60.—Type FM Resistance Units. Gen. Elec. Co.

capacity. It is made in several standard sizes and in special cases taps are brought out to meet requirements, though ordinarily there are but two taps, one at each end.

Field Rheostats.—Resistance units of small current capacity find frequent use in rheostats for controlling the shunt field current of motors. The rheostat switch is usually combined with other parts of the controlling device as shown by typical examples described in later chapters. In some installations, however, the field rheostat is entirely separate and then consists of a revolving switch arm, pivoted at the center, which makes contact on a series of terminals to which taps from the resistance units are connected. Fig. 61 shows the general appearance of a common form of field rheostat and an elementary diagram of the connections. The resistance is a crimped wire embedded in enamel on the back of the cast-iron plate.

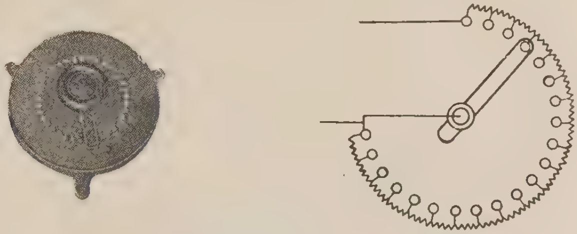


FIG. 61.—Field Rheostat.

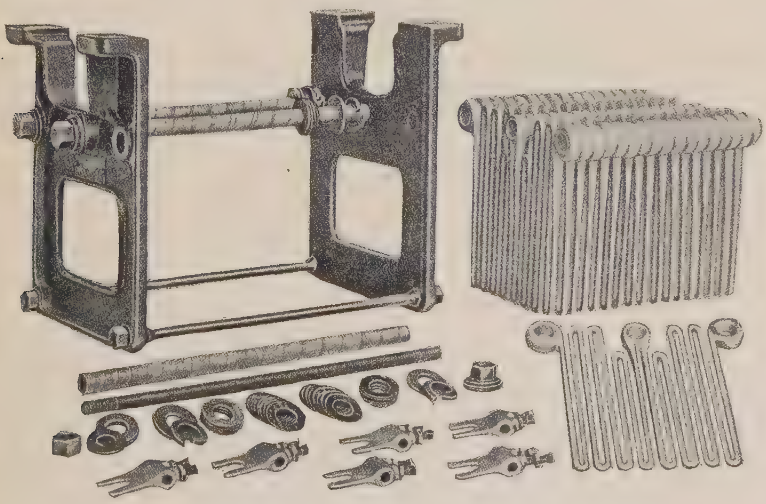


FIG. 62.—CG Rheostat. Disassembled View. Gen. Elec. Co.

Cast Grid (CG) Resistance.—Used where large currents flow intermittently, as in motor starting resistance. The units are of cast iron of the shape shown and are assembled on insulated rods in a cast-iron frame. The IG type is very similar, the grids being of different shape and size.

CH Grid Resistance.—This is of the same general type and purpose as the CG resistance. A more compact form of the CH grid is known as the Westfield type.

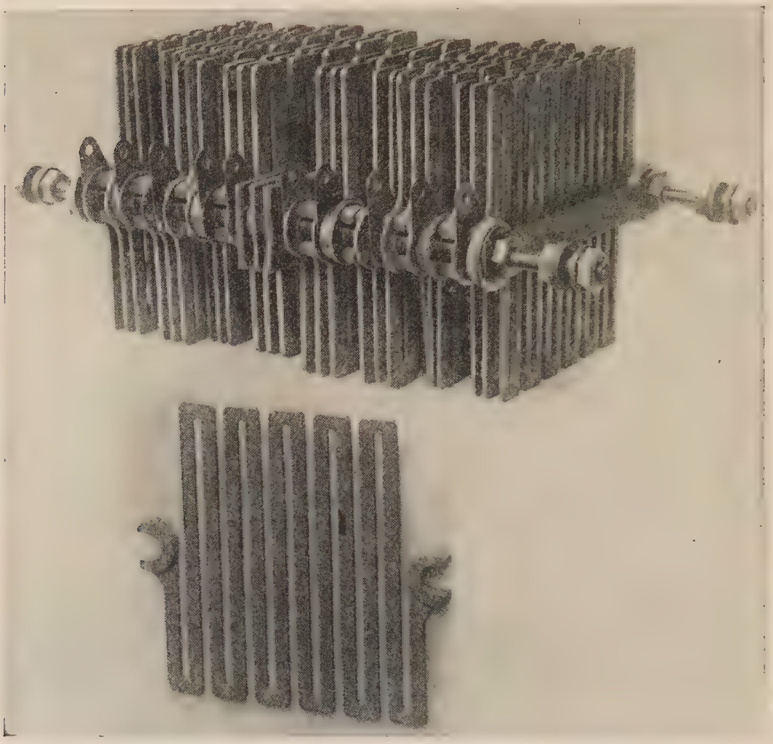


FIG. 63.—CH Grids. Cutler-Hammer Elec. Co.

CIRCUIT BREAKERS.

The automatic circuit breaker is a device for automatically opening a circuit when the current exceeds a predetermined strength. It consists essentially of a switch which in its closed position is held by a latch against the pressure of a spring tending to open it. The latch is released by the movement of the armature of an electromagnet which carries the line current. The distance between the armature and the magnet may be varied, thus varying the amount of current necessary to cause the breaker to open.

Circuit breakers supplied by various manufacturers are used in the navy, those of the Cutter Company having been selected for description because they illustrate very well the construction of the device, and the uses to which it may be put.

I. T. E. Circuit Breakers.

The Cutter Electrical and Manufacturing Company manufactures a great many different styles and types of circuit breakers designed to afford protection under all conditions of load. Those that have been installed on switchboards of recently built ships are designated by their governing feature, such as **overload, no voltage, shunt trip, time limit** and **reverse current.** Some contain but one of these operating features, while others may contain different combinations, dependent on the circuits to be protected and the service to be performed.

Overload.—The governing principle of the I. T. E. overload circuit breaker is illustrated in Figs. 64 and 65. The current from one side of the circuit enters the circuit breaker at A, passes through the laminated bridge B to contact block C, thence through coil D and terminal E to the line. The coil D surrounds a magnetic core, having pole pieces F and G and armature H. The effect of the current in the coil is to energize the magnet, thus tending to lift the armature against its own weight. The strength of the current required to trip the circuit breaker is determined by the position of the armature, which is readily adjustable for a range of values indicated on the calibration plate P.

When the current passing through the circuit breaker attains sufficient strength, the force produced by the magnetic coil overcomes the weight of the armature H, and the latter is drawn upward towards the pole pieces with constantly increasing force, until it strikes the projection L, which, in turn, operates the restraining latch M, and the switch member opens in response to the force supplied by the spring of the contact member and auxiliary springs provided for the purpose.

Positiveness in opening is further assured by the blow of the armature which is added to the other opening forces; hence the heavier the overload, the more violent the blow and the quicker the circuit breaker opens, or the greater the current the more promptly it is interrupted. This is the I. T. E. of Inverse Time Element principle.

An inspection of Fig. 64 will show the method of setting the circuit breaker so that it will operate at a given current. The greater the distance of the armature from the pole pieces, the greater must be the current through the coil to produce sufficient force to move it. To allow the switch member to open on a less current, it is but necessary to shorten the distance between the armature H and the poles F and G. This is accomplished by moving the knurled knob to the left, which raises the armature.

In the circuit breakers designed to carry heavy currents the coil D is dispensed with, and the main current is led through and between the legs of a

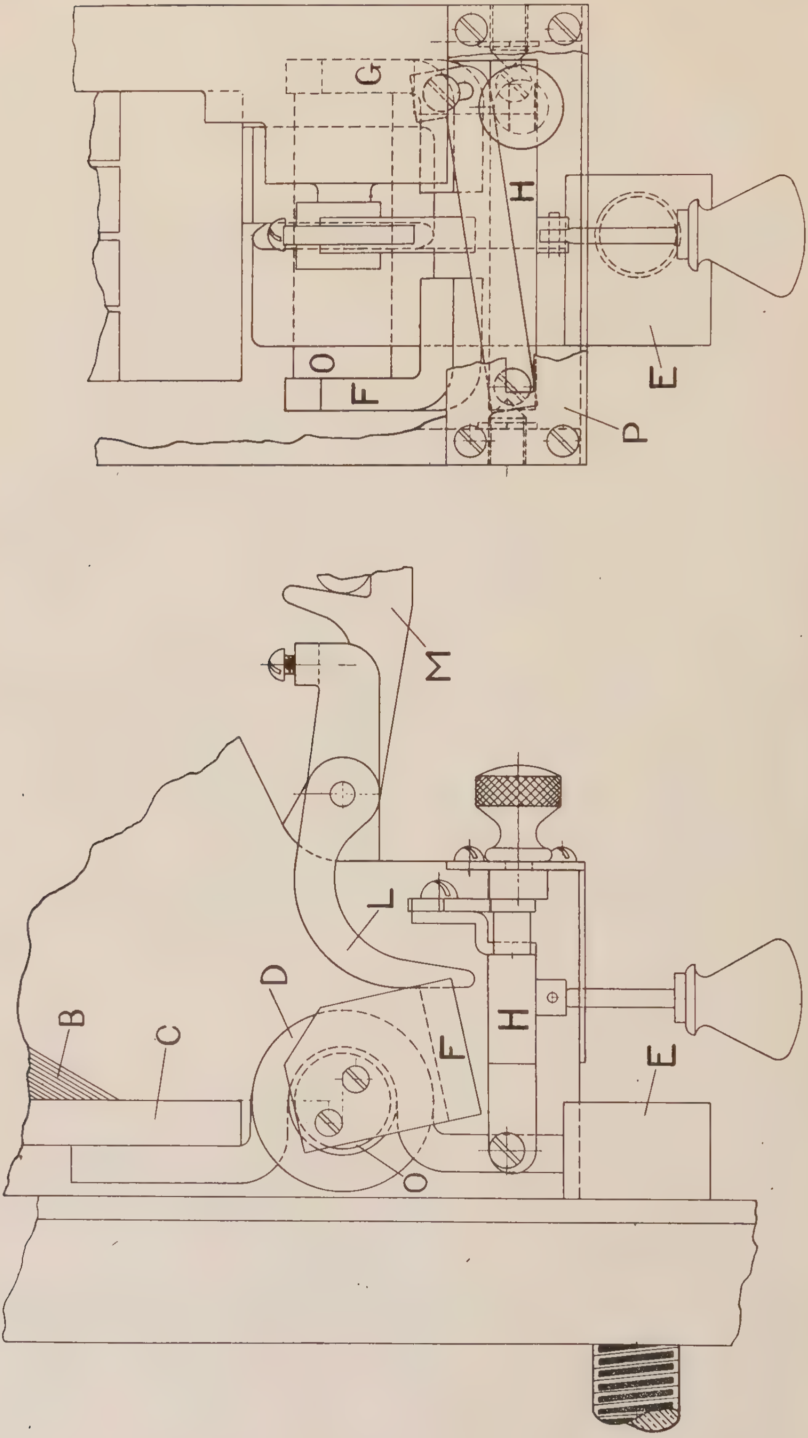

G
H
O
F
E
P
M
L
D
B
C
H
F
E
O

FIG. 64.—Showing Operating Features of Overload I. T. E. Circuit Breaker.

horseshoe-shaped magnetic circuit, which lies flat against the base of the breaker and is fitted with pole pieces. The current flowing in the main line induces poles of opposite polarity in the pole pieces, and on attaining sufficient strength a swinging armature is drawn upwards towards the poles. The upward movement of the armature actuates the releasing mechanism and the switch member opens.

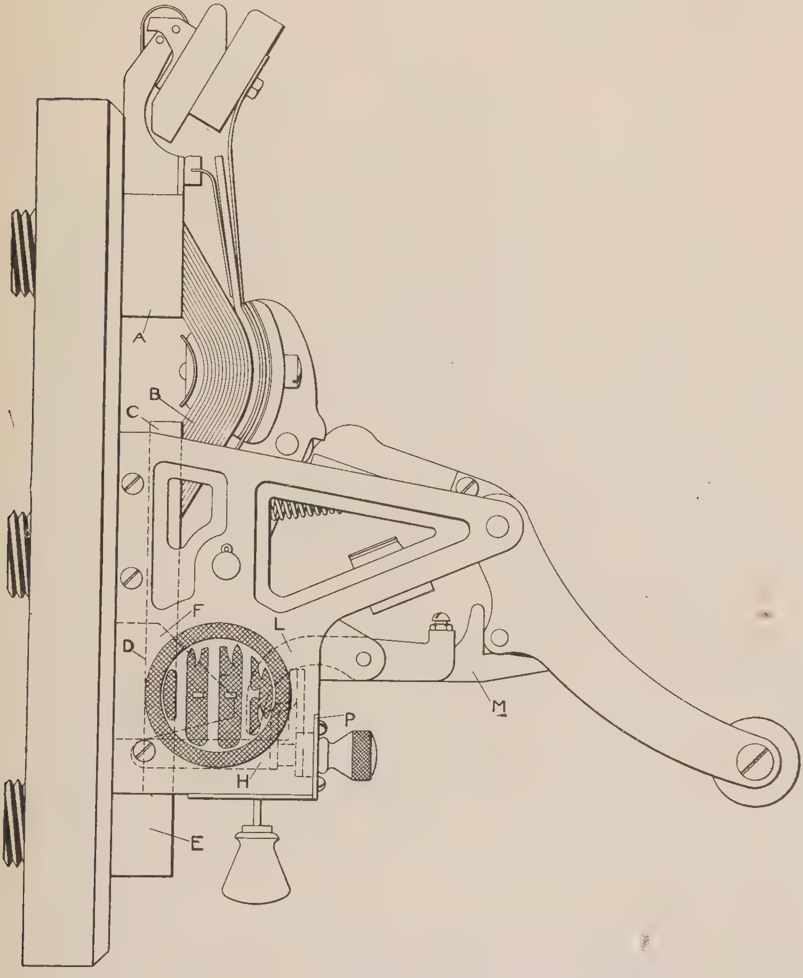


FIG. 65.—Plain Overload I. T. E. Circuit Breaker.

Double-Arm Type.—A circuit breaker with a separate controlling handle for each line wire is referred to as a double-arm breaker. The Cutter Company applies to this type the term "Dublarm." The arms ought not to be closed simultaneously because one arm should always be free to trip in case overload conditions exist. The tripping mechanism is arranged to trip both arms when an excessive current flows in either line wire.

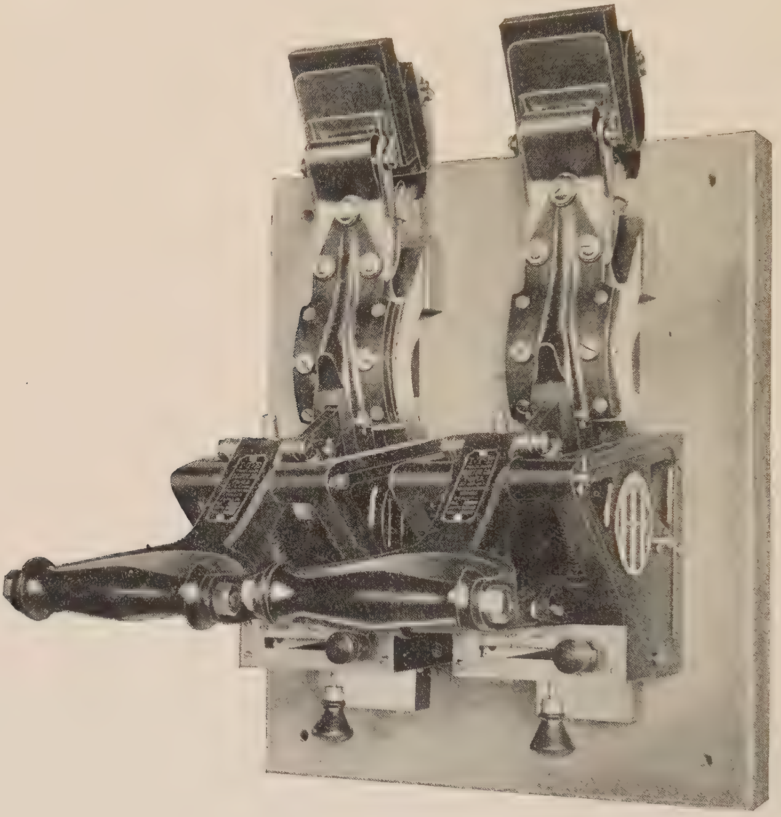


FIG. 66.—Dublarm Overload I. T. E. Circuit Breaker.

No Voltage.—The "No-Voltage" circuit breaker automatically opens the line upon failure of the supply voltage. This feature is generally combined with the overload feature, though it has its uses as a separate device. When there is voltage on the line and the switch arm is closed, a circuit is closed through a separate magnetic coil, which becomes energized. The pole pieces of this coil attract an armature which is so arranged mechanically that in moving, it releases a catch which allows the switch arm to be closed, but on failure of voltage, the armature is pulled back under the action of springs and a blow is given to the holding catch which releases the switch and immediately opens it. If there is no voltage on the line the switch member cannot be kept closed unless the catch is held up by hand. One terminal of the no-voltage coil is connected to one side of the line and the other terminal is connected to the other side of the line, through a plunger switch which is closed only when the breaker is thrown in.

Shunt Trip.—There are many conditions arising which necessitate the prompt opening of a circuit independent of the load upon the circuit, and circuit breakers may be installed in places which are inaccessible for prompt opening by hand. Cases may also arise where circuit breakers are installed on a switchboard and it is desirable to open them from another station. In such cases, the breakers are fitted with the shunt-trip feature. This consists of an extra coil wound as an electromagnet with its circuit broken by a push button or switch which may be remotely and conveniently installed for operating. The terminals of this electromagnet are arranged similarly to those described under the no-voltage feature. Ordinarily current does not flow through the magnet coil, but when it is desired to open the breaker, the operating switch is closed, which energizes the coil. This operation actuates an armature in conjunction with its pole pieces, and the movement of the armature causes a blow to be given to the holding catches and the switch arm opens.

Direct Acting Time Limit.—The circuit breaker, as ordinarily made, responds immediately to overload or short circuit, and where the overload is suddenly applied, the circuit breaker frequently opens before the ammeter has time to indicate the value the current attains. In many cases this immediate action is necessary, but there are cases in which it is desired to have the circuit opened after the overload has been maintained for an appreciable period of time.

In those circuit breakers fitted with the time-limit device a cylindrical vessel at the bottom contains a seat for a circular disc which is suspended from the tripping armature. This feature may be seen in Fig. 67. The engaging faces of the disc and its seat are accurately surfaced, and the disc is supported in such a manner that it may perfectly align itself with its seat. The disc and seat are immersed in a shallow bath of specially prepared oil, serving to exclude air from between the engaging faces, which are thus separated only by a thin film of oil. The intimate engagement of the disc with its seat causes a restraint upon the armature.

In the event of overload, the pull of the armature communicated to the disc causes gradual extension of the oil film, until, if the overload be sufficiently long continued, the film is finally ruptured, the disc is suddenly released and the armature now moves forward without restraint and the circuit is opened in the usual manner. The force necessary to rupture the oil film is considerable, though the movement of the disc during the interval up to the time it is ruptured is exceedingly small.

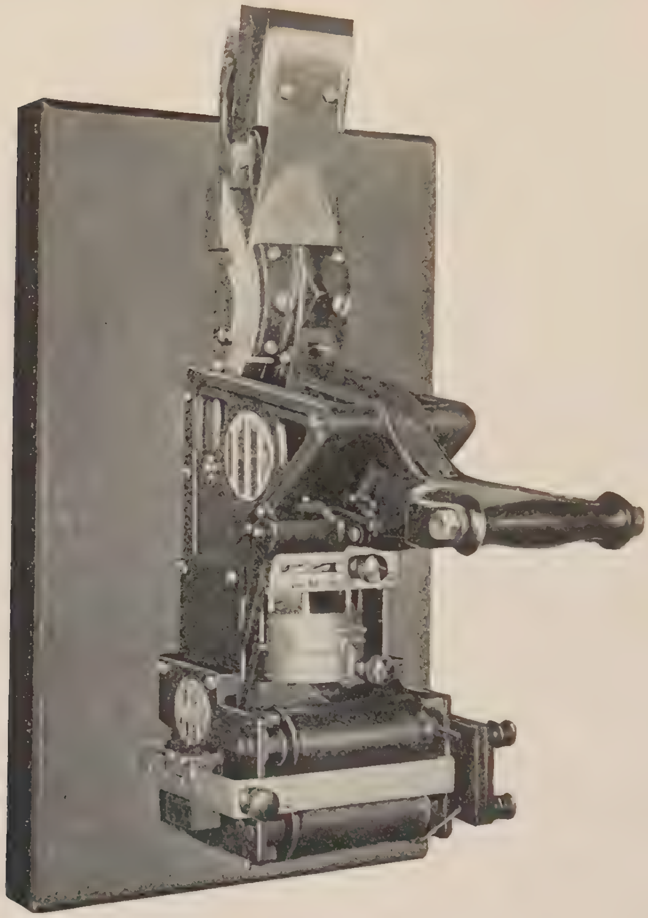


FIG. 67.—I. T. E. Circuit Breaker Fitted with Overload and Reversal Features and Time-Limit Device.

To separate the disc from its seat, a definite amount of work must be done; the stronger the pull by the armature the quicker the work will be done.

The time element is, therefore, inversely proportional to the pull of the overload magnet and this in turn is proportional to the square of the current. In general terms, the time required to cause the opening of the breaker is inversely proportional to the square of the current.

For circuit breakers used to protect large generators the time element is made adjustable. This is accomplished by reducing the contact area of the disc with its seat by slight depressions extending over a portion of each surface. When the seat is turned so that these depressions are opposed, the surfaces engage over a maximum area. An angular movement of the seat from this position displaces the depressions with reference to each other and causes proportional reduction in the area of engagement. The seat may be turned by a small knob which moves over a scale upon which the relative time calibrations are indicated. The overload setting is effected in the usual manner by moving the armature towards or away from the magnet, as the current at which the circuit breaker is required to operate is to be decreased or increased. The time-limit device is moved simultaneously with the armature, so that the relation between the two remains unaltered.

Reverse Current.—I. T. E. circuit breakers fitted with the reversal operating feature are designed to allow flow of current in one direction, but to open automatically if by chance the current becomes reversed. These serve many useful purposes, but as used on Navy-type switchboards, they serve to protect generators running in parallel if anything happens to one unit to materially lower its voltage. When running in parallel all generators should deliver their share of the current. In case of accident to one generating unit, which causes a drop of voltage, this unit not only will cease to deliver its full proportion of load, but the others in parallel with it will force current into it, tending to stop it and run it as a motor. The good machines will be protected by their overload breakers before serious damage is done to them or possibly to the damaged unit, but the whole service will be put out of operation until normal conditions are again reached. If fitted with reverse current breakers, the crippled unit will be automatically disconnected, and though the load on the others may be increased, the service is not interrupted.

Where each generator is protected by such reverse current breakers, no unit can be effectually thrown into parallel with others until it is up to voltage.

The operating features of this type of breaker are illustrated in the elementary diagram shown in Fig. 68, and may be seen at the bottom of Fig. 67.

The leads marked + and − are connected to the terminals of the generator and when the circuit breakers are closed they deliver current to the bus bars A and B, to which other generators may be connected in parallel.

The reversal feature is accomplished by the co-operation of two electromagnetic systems; one shown on the left consists of an electromagnet whose winding is in series with the main current; the other on the right consists of two electromagnets wound so that each gets full-line potential, but connected as a shunt across the line. The series magnet has a pivoted core to which are secured the pole pieces; the whole may revolve without moving the winding. The normal position of these pole pieces, one of which is shown, is midway between the polar extensions of the cores of the other two electromagnets, and they are supported in this position by stops on which they rest, but they are free to move upward.

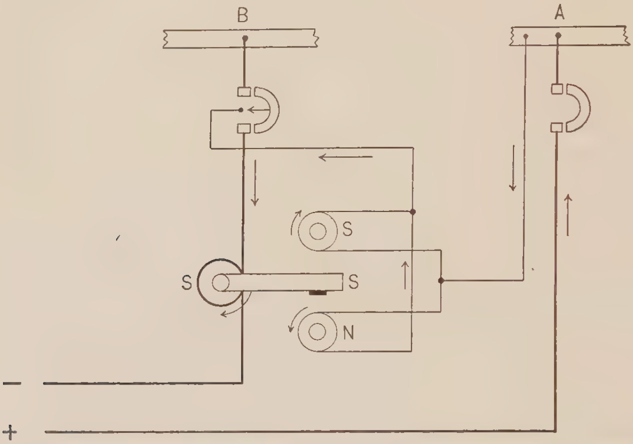


FIG. 68.—Operating Circuits of I. T. E. Reverse Circuit Breaker.

When the left-hand switch member is closed, the circuit through the two shunt electromagnets is closed and they are energized, and with the direction of current as indicated by the arrows, the near pole of the lower one is of N polarity, and the upper one is of S polarity. At the same time, the main current, flowing through the series magnet, produces S polarity in the near pole. The extension of each pole piece is then held in its normal position by the attraction of the lower of the shunt electromagnets and by the repulsion of the upper one, as well as by gravity.

If the bus bars become of a greater voltage than the generator, due either to a rise in the voltage of another generator that may be connected to them, or to a lowering of the voltage of the generator itself, current will flow in a reverse sense through the circuit breakers, but at the same time, it will be noted that *the direction of current through the shunt electromagnets will remain unaltered,* as the polarity of the bus bars is not changed.

This reversed current flowing through the series magnet coils changes the polarity of its poles and pole pieces, and the near pole and pole piece become of north polarity. The extension of the pole piece secured to the core will now be attracted upwards by the attractive force of the upper shunt magnet and the repulsion of the lower one, and the system will turn on its pivots, so as to make a closed magnetic system between the series and the upper shunt magnet. The upward motion of the extended pole piece, delivers a blow to the holding catch and the switch member opens.

In another type of reverse current breaker, the series coil is dispensed with, and one side of the main current is led through and between the legs of a flat, vertical, horseshoe-shaped magnetic circuit, secured on the back of the circuit breaker panel, with the curved surface of the horseshoe uppermost. On each leg of this magnetic circuit and at right angles to it are secured, through the supporting panel, the cores of two electromagnets parallel to each other, a short distance apart and one over the other. These four electromagnets are so wound in series as to make their poles of opposite polarity; thus on one leg of the circuit, the poles away from the panel are N and S, and on the other leg they are S and N, and the poles at the panel are of opposite polarity respectively.

Facing the near poles of the electromagnets and pivoted between them on horizontal pivots is a vertical swinging armature, with its faces so beveled that when swung one way or the other they lie flat against the faces of the cores. In its normal position this armature hangs vertically, but is so mechanically connected with a sliding weight that a greater or less force will be required to tip it, and ordinarily this weight is in such position that it tends to hold the armature in its normal position.

The windings of the electromagnets receive full-line voltage when the switch member is closed as they are connected as a shunt to the main circuit. As the windings of all are practically the same, the pole strengths of all four magnets due to the shunt current are equal, and both upper and lower systems of poles exert an equal pull on the upper and lower faces of the swinging armature. However, when the switch member is closed, the main current flows through the breaker, and it induces a magnetic circuit in the magnetic material, either weakening or strengthening the poles of the upper cores of each system of magnets. With the current in one direction and the upper poles weakened, the armature remains in its normal position, attracted more strongly by the lower poles. When the main current through the breaker is reversed, the direction of current through the shunt magnets remaining the same, the upper poles are strengthened, with the result that the balance of the armature is upset and its upper half is attracted to the poles. This movement actuates an arm which conveys motion to the releasing catch and the switch member opens.

The strength of current required to trip the armature is governed by the position of the sliding weight.

FUSES.

The safety fuse is, like the circuit breaker, a device inserted in a circuit to break that circuit in case a predetermined strength of current is exceeded. It consists essentially of a conductor with a low melting point which will melt and break the circuit when an excessive current flows.

The requirements of a fuse are: that it should melt without throwing out fused metal, that it should have hard terminals, and that it should be long enough to prevent an arc forming after the fuse is melted.

The substances generally used are lead, or an alloy of lead and tin, called "half-and-half" solder. Sometimes bismuth is added to lower the melting point.

FIG. 69.—Cartridge Fuse.

The type usually used for motor control panels is the cartridge fuse, illustrated in Fig. 69. The fuse conductor is enclosed in an asbestos cartridge and attached to the knife blade contacts at each end, which fit into spring clips, allowing easy insertion and removal of the fuse. In fuses for circuits of less than 61 amperes capacity the knife blades are omitted, and the fuse conductor is attached to the brass end ferrules, which fit into circular spring clips; this type being known as the cartridge fuse with ferrule contacts.

Rating of Fuses.—Navy fuses are rated according to the National Electric Code, and the rating in amperes is stamped on the fuse. This rating is 80 per cent of the current that the fuse will carry indefinitely. But, since it takes an appreciable time for a fuse to melt on overload, depending on the temperature of the air, the temperature of the fuse when the overload begins, and the ease with which the fuse radiates heat, a fuse will, under normal conditions, carry a current greatly in excess of its rating for some minutes. The following table is taken from the 1915 edition of the National Electric Code:

RATING OF CARTRIDGE FUSES.

Rated Capacity.	Contact.	Will Blow on 50 Per Cent Overload (Starting at 75° F.) in
0- 30 amperes	ferrule	1 minute
31- 60 "	"	2 minutes
61-100 "	knife blade	4 "
101-200 "	" "	6 "
201-400 "	" "	12 "
401-600 "	" "	15 "

Since most service motors are designed to carry 100 per cent overload for short intervals, it is customary to use fuses rated 50 per cent in excess of the normal full-load current of the machine. Thus, a 100-ampere motor would be provided with 150-ampere fuses. These will carry, under normal conditions, 150 per cent of 150, or 225 amperes, for six minutes. The motor circuit breakers would be set for slightly more than 200 amperes, the fuses being designed to blow only if the circuit breakers fail to function.

Comparison of the Fuse and the Circuit Breaker.—They are alike in that the greater the overload the quicker the action. The fuse is absolutely certain to blow on overload, but its time interval is variable. The circuit breaker is not certain to blow on overload since it may get out of order like any other mechanical device, but it responds very quickly to slight overloads. Its time element does not depend on external circumstances and in some designs is adjustable. It is easier to close a circuit breaker than to replace a fuse, and the circuit breaker may be closed from a distance by means of an auxiliary circuit. The no-voltage release, reverse-current release, hand trip, shunt trip and other features of the circuit breaker are not possessed by the fuse. Consequently, it is customary to protect a motor with both fuses and circuit breakers, combining the certain action of the one with the convenience of the other. The circuit breaker is set to blow at a smaller current than the fuse, so that the fuse acts only if the circuit breaker fails. A sudden very heavy overload, however, usually blows everything in the line.

SWITCHES.

A switch is a device for making, breaking, or changing connections in an electric circuit. The requirements for a switch are low resistance, current capacity as great as the rest of the circuit, low resistance at contacts, and quick action to make and break. The construction and installation should be such as to minimize the possibility of accidental movement from the effects of vibration or the weight of the moving parts.

Switch Designations.—

A **single-throw switch** closes a circuit only when thrown in one direction.

A **double-throw switch** may be thrown to either of two closed positions.

A **single-pole switch** closes only one leg of a circuit. It usually consists of one blade, though sometimes two or more blades in parallel are used.

A **double-pole switch** closes both legs of a circuit and must have at least two blades.

A **multiple-pole switch** closes more than two legs of a circuit. Three-pole, four-pole and six-pole switches are not uncommon.

Knife Switches.—A D. P. S. T. (double-pole, single-throw) knife switch is illustrated in Fig. 70. This type is sometimes called a "lever switch." Conducting parts are of copper. The moving conductors are called the blades and the contacts into which they fit are called the clips. The clips are supported on copper clip blocks. The handle is of hard wood or composition.

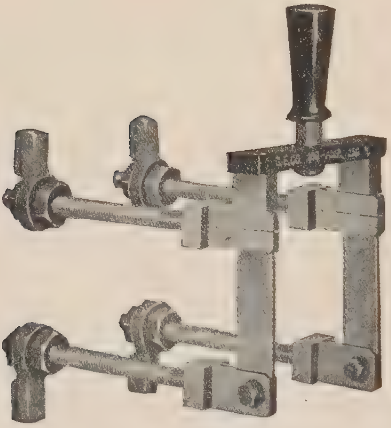


FIG. 70.—D. P. S. T. Knife Switch.

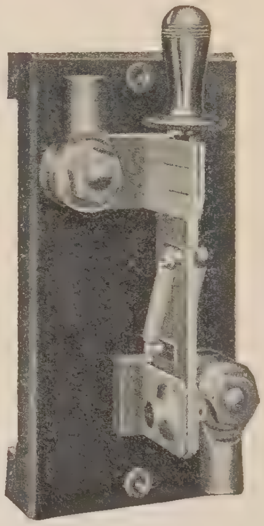


FIG. 71.—S. P. S. T. Quick-Break Knife Switch.

Quick-Break Knife Switches.—These are used to insure quick opening of high-voltage or inductive circuits, to avoid drawing an arc. One blade is opened by the handle and is attached to a second blade by means of a spring. The secondary blade is pivoted to the main blade with a small range of motion which is limited by a stop. The two blades are held in contact by the spring except in opening the switch. The final break of the circuit is made by the secondary blade which is snapped away from the clips by the action of the spring.

Push-Button Switches.—These are used for controlling small motors driving galley and laundry appliances and the like where the operators know nothing about the machinery. The idea is to arrange the connections so that the motor is started by simply pressing a button. The principle is illustrated in Fig. 72. The + line to the motor is interrupted by a switch which is normally held open by its weight or by a spring, and is closed by the attraction of a solenoid.

The exciting current for the solenoid flows from the + to the − line around the solenoid and through two push-button switches. The "on" switch is held open by a spring and the "off" switch is held closed by a spring. To start the motor, the "on" switch is pressed, completing the solenoid circuit. The solenoid closes the main line switch and starts the motor. The "on" button may then be released and the solenoid remains energized through the circuit taken off the main line at P. To stop, the "off" switch is pressed, breaking the solenoid circuit and allowing the main switch to open. The "off" switch may then be released. With this arrangement the push buttons may be placed at a distance from the motor and connected to it by wires much smaller than those required to carry the motor current.

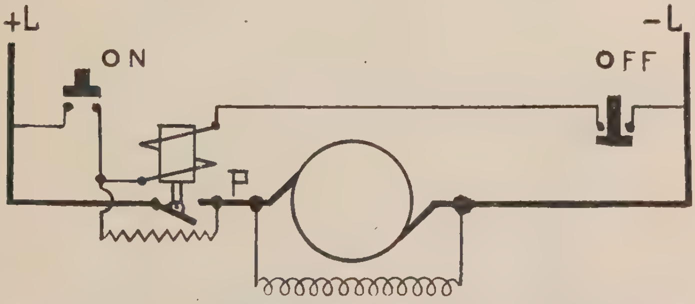


FIG. 72.—Elementary Diagram of Push-Button Switch for Motor Starting and Stopping.

The main switch is of the clapper type described below.

If starting resistance is used, it is cut out by automatic switches.

CONTACTORS.

Contactors or **clapper switches** are switches which are normally held open by their weight, and are closed by a solenoid, remaining closed only so long as the solenoid is energized.

There are two general types: the **shunt contactor** in which the actuating solenoid is in a shunt circuit, as illustrated in Fig. 72, and the **series contactor** in which the main-line current energizes the solenoid.

Shunt Contactors.

Several varieties are used in the Navy, but the differences between them are of form only; all work on the same general principle which is illustrated by the two General Electric Company contactors shown in Figs. 73 and 74.

Operation.—The main-line current enters at L (Fig. 73), flows through the **blow-out coil** A (Fig. 74), to the upper contact B′ (Fig. 74), to contact B (when closed), to flexible conductor C, and out to the line at LL (Fig. 73). The function of the blow-out coil is to rupture the arc formed at break; the poles of the coil are extended by iron side pieces F which direct the flux across the contacts. Inside the side pieces are heavy sheets of asbestos composition G, forming an **arc chute**; the heat of the arc expands the air within the chute, thus assisting the magnetic field of the blow-out coil to drive the arc to the front and upwards, away from the contactor. The **actuating coils** E are wound in series and are connected in a shunt circuit, called the **pilot circuit**, the terminals of which are at D and DD. When the actuating coils are energized, the arm carrying the lower contact, which is pivoted on pin K, is attracted and closes the main circuit. The magnetic circuit of the actuating coils is indicated by a dashed line in Fig. 73. The

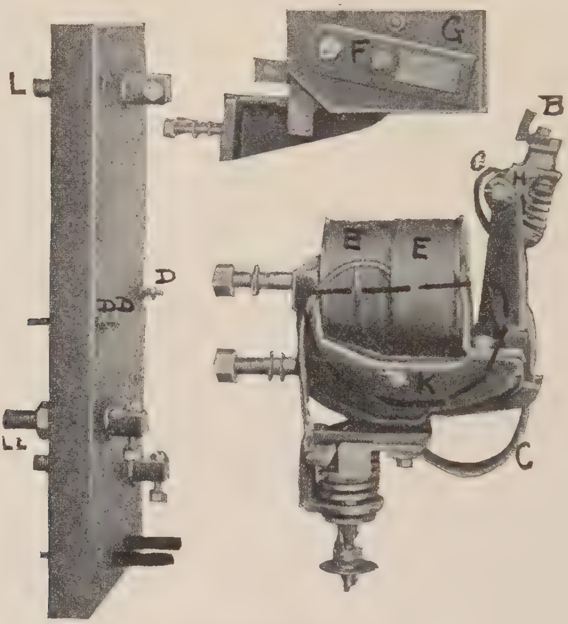


FIG. 73.—Direct-Current Shunt Contactor.
Gen. Elec. Co.

moving contact B is pivoted at H, and, when closed, compresses the small helical spring on the front of the contactor, thus assuring a firm pressure between B and B′. Heavy duty contactors are provided with secondary carbon contacts to take the arc at break, as in the ordinary circuit breaker.

Uses of Shunt Contactors.

Contactors are quite generally used on board ship for starting and controlling motors. For distant control they are very convenient, because the small current required to operate the actuating coils may be carried in light flexible leads. The heavy conductors that supply the armature current lead direct to the motors, which may be started, stopped, reversed, and controlled as to speed by contactors on the motor panel, the contactors are actuated by a small controller placed in any part of the ship, the only leads to the so-called **master controller** being the small pilot circuits. The contactors may be arranged to cut out starting resistance, to automatically slow a motor if it exceeds a predetermined limit of power, and to perform the function of circuit breakers. Contactor panels may be arranged in many different ways to accomplish these results as illustrated by examples

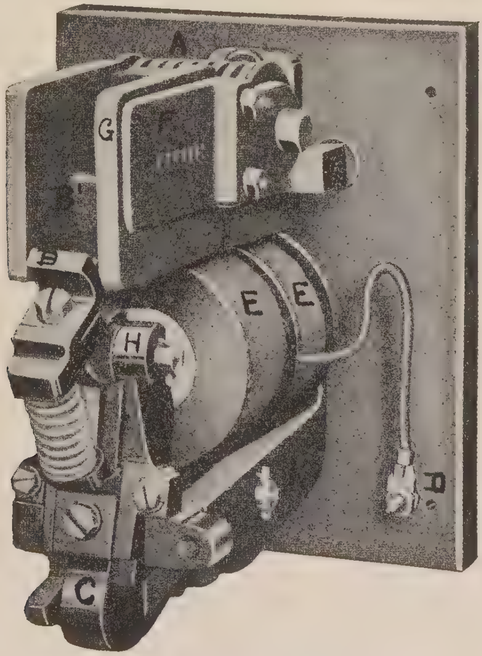


FIG. 74.—Direct-Current Shunt Contactor.
General Electric Co.

in the chapter on " Application of Motors," but the operation depends on the few elementary principles discussed below.

To Start a Motor.—The use of a contactor to start a small motor has been explained in connection with the push-button switch on page 69. The push-button switch may be replaced by any device that will make and break the pilot circuit. The usual arrangement is a master controller that performs other functions in connection with controlling the motor, such as cutting out starting resistance, or operating the shunt-field rheostat.

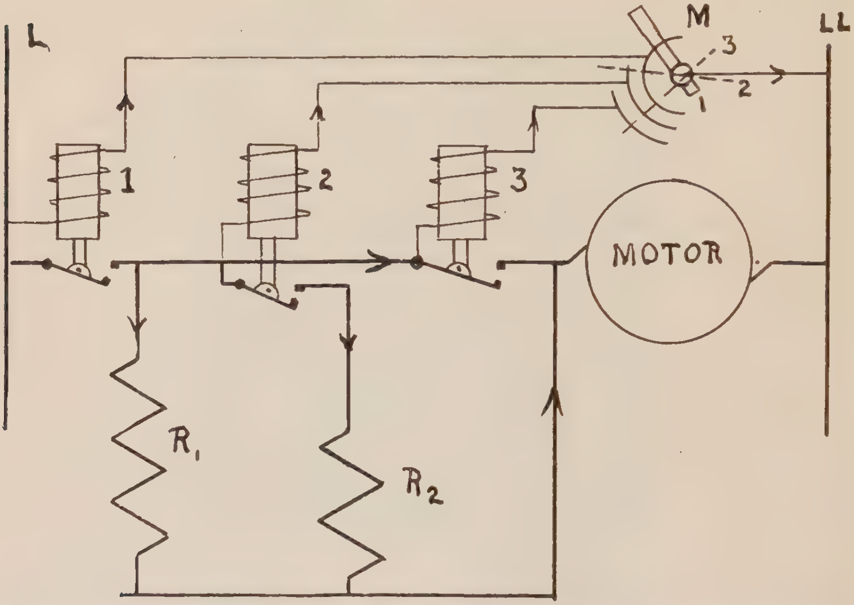


FIG. 75.—Elementary Diagram of Line and Accelerating Contactor Controlled by Master Controller.

To Cut Out Starting Resistance with a Master Controller.—Fig. 75 shows an arrangement of three contactors to start a motor and to cut out the starting resistance in two steps. M represents the master controller. When M is in position 1, the pilot circuit of **line contactor** 1 is energized; 1 closes, feeding current to the motor through resistance R_1. Moving the handle of the master to position 2 causes the **accelerating contactor** 2 to close, putting R_2 in parallel with R_1. Moving the handle of the master to position 3 causes **accelerating contactor** 3 to close, cutting out all the starting resistance. The motor is stopped by moving the handle of the master off all three circular contacts, thus allowing the three contactors to fall open. The terms " line contactor " and " accelerating contactor " refer to the functions the contactors perform; they are alike in construction.

To Cut Out Starting Resistance Automatically.—Contactors used for this purpose are fitted with a **series relay**. This consists of a solenoid in the main line which controls the pilot circuit of a contactor. A series relay is shown attached to the bottom of the contactor in Fig. 73. The two pins at the bottom of the panel are the terminals of the pilot circuit of another contactor. The small copper disc attached to the plunger of the relay coil normally bridges across the pins and completes the circuit, but is lifted off them when sufficient current flows in the relay coil. Their function is illustrated in Fig. 76. Closing the master switch M operates line contactor 1, feeding current to the motor through series relay S_1 and resistance R_1. The first rush of current causes S_1 to lift the disc beneath it, breaking the pilot circuit to accelerating contactor 2. The back E. M. F. of the motor increases as it gathers speed and the current in S_1 gradually falls until it becomes too weak to hold the plunger, which drops, completing the pilot circuit to contactor 2. Contactor 2 then closes, putting R_2 in parallel with R_1. The first rush of current through series relay S_2 breaks the pilot circuit to contactor 3. After a further increase in the back E. M. F. of the motor, S_2 drops its plunger, causing 3 to close. In closing, contactor 3 lifts the disc *d* (which is mechanically attached to some moving part), and thus breaks the pilot

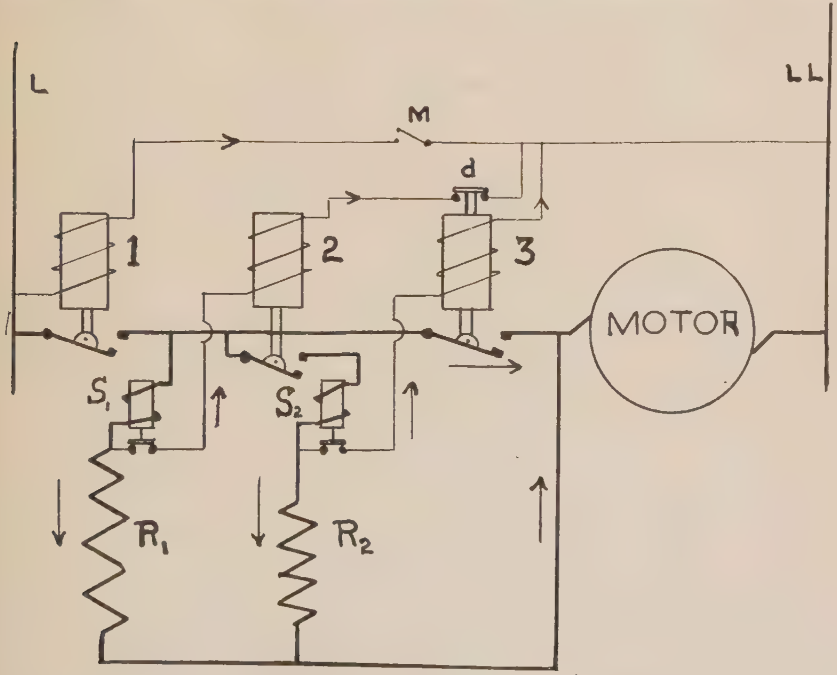


FIG. 76.—Elementary Diagram of Automatic Accelerating Contactors.

circuit of contactor 2, which falls open. This is to save the current that otherwise would be wasted in holding contactor 2 closed; there being no necessity for a circuit through R_2 when 3 is shut.

Current Interlocks.—The pilot circuits of automatic accelerating contactors may lead to a master controller instead of direct to the negative line. In this case the three pilot circuits are identical with those of Fig. 76 until they leave the actuating coils, when they pass into the master controller as shown in Fig. 75. The starting resistance (which may serve as regulating resistance also) is thus under the control of the operator, but the series relays insure that the accelerating contactors will close in sequence and at proper intervals, even if the master is thrown from "stop" to the "full-speed" position without halting at intermediate points. The series relays when used in this way are sometimes called **current interlocks.**

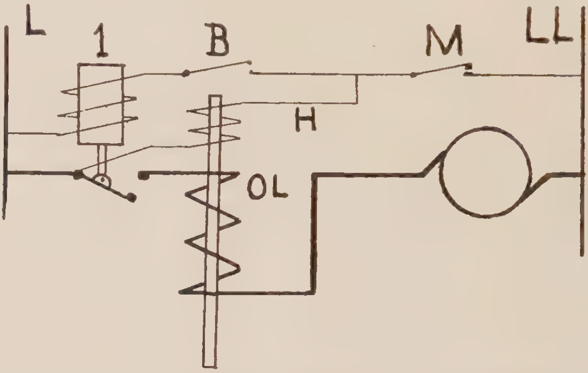


FIG. 77.—Elementary Diagram of Line Contactor with Overload Release.

Contactors with Overload Release.—In Fig. 77 OL is a solenoid in the main line. B is a switch hinged at the left and held shut by its weight. M represents the master controller. When excessive current flows in the main line, the **overload relay** OL raises its plunger and opens the **overload bridge** B. This de-energizes the actuating coil of the line contactor, which opens, stopping the motor. The **holding circuit** H, of high resistance, carries enough current to hold up the plunger when it is raised by the relay coil. Its function is to keep the bridge open after it has been raised by the action of OL. It may be seen from the diagram that without this device the line contactor would continuously open and close if a permanent overload occurred. To "set the circuit breaker" the master switch M is opened. This allows the bridge to fall shut and the motor may then be started again in the usual manner. In the master controller as actually constructed, the break at M is made when the controller is in the "stop" position; M being closed in all other positions. This insures that after an overload the motor cannot be started until all the starting resistance has been cut into the circuit.

It should be noted that the construction of all contactors is such that they open on low voltage, through failure of current in the actuating coils.

Accelerating Contactors with Overload Release.—In some cases it is desirable that a motor should merely slow down on slight overload. For example, steering-gear motors are frequently overloaded and it would be dangerous to have them stop every time an overload occurred. They are, therefore, controlled by contactors which automatically cut in one or more sections of the starting resistance when the line current becomes too great. The elementary principle involved is indicated in Fig. 78. P_1, P_2 and P_3 are pilot circuits, P_1 leading to the line contactor, and P_2 and P_3 to accelerating contactors. SS_2 and SS_3 are **slow-speed magnets**, formed by coils in the motor circuit. SS_3 raises its plunger on a slight overload, opening the bridge B_3 and allowing one accelerating contactor to open. This cuts in the last section of the starting resistance. If the overload still increases, SS_2 operates, cutting in another section of resistance. The plungers of the slow-speed magnets rest against stops when in the bottom position. These stops are adjustable, and by means of them the magnets are set to operate on any desired intensity of current; the higher up in the coil the plunger is, the less current is required to move it. There are no holding coils, so the bridges close and the starting resistance is cut out automatically when the cause of the overload is removed. A regular overload release is also fitted to the line contactor to protect the line in case of short circuits.

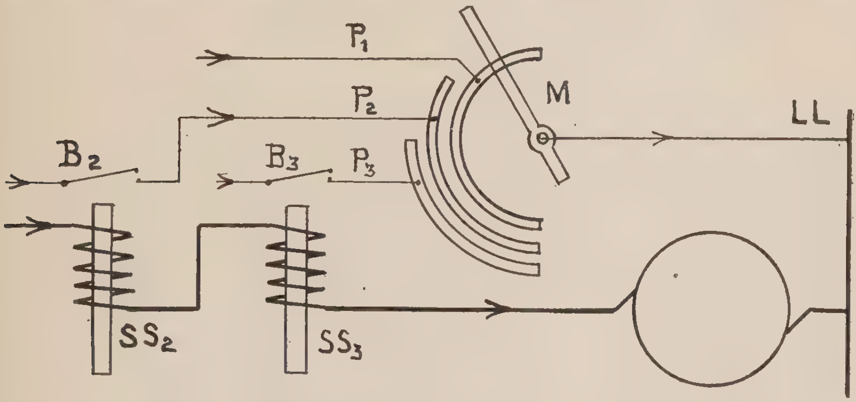


FIG. 78.—Elementary Diagram of Connections of Slow-Speed Magnets.

Contactors for Strengthening Field on Overload.—Shunt motors with field-rheostat control may be overloaded by cutting in the field resistance too rapidly. A contactor may be connected as in Fig. 79 to prevent damage from this cause. The main line current flows to the motor around the coils of the slow-speed magnet SS. The shunt-field current flows through the upper half of the switch arm of the field rheostat M. The field resistance is short circuited when the contactor 7 is closed. The pilot circuit of contactor 7 is completed through the **holding resistance** H and the bridge B in parallel, and the segment T on which the lower half of the rheostat switch arm makes contact. If the field resistance is cut in too rapidly, the sudden rush of armature current draws up the plunger of SS

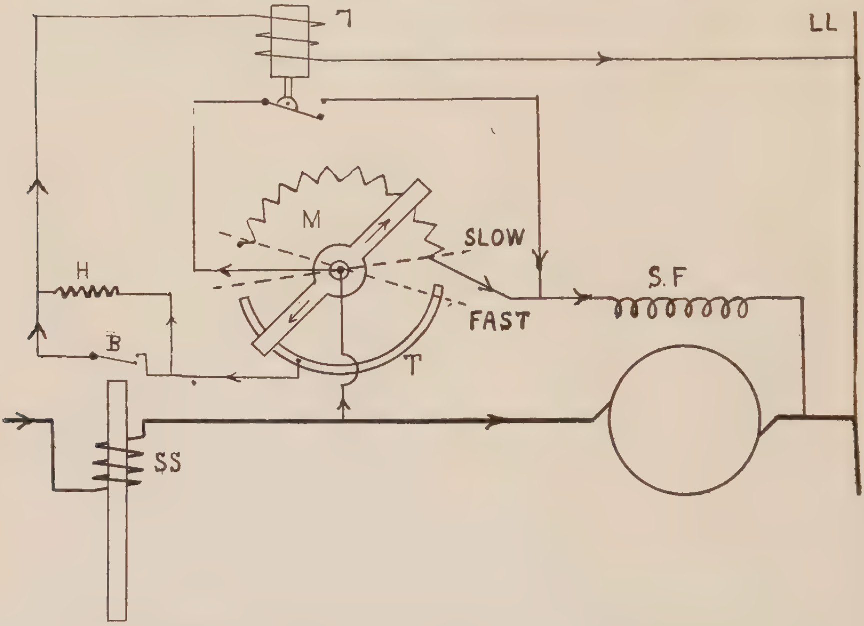


FIG. 79.—Elementary Diagram of Contactor to Short Circuit Field Resistance on Overload.

and closes B. Contactor 7 then closes, short circuiting the field resistance. The armature current is thus immediately reduced and the bridge falls open, but the contactor is held shut by current through the holding resistance H, which allows the flow of sufficient current to *hold* 7 shut, but not enough to *close* 7 when it is open. To de-energize the contactor, the switch arm must be moved to "slow." This cuts out all the field resistance, and the switch arm moves off T, allowing 7 to open. An overload due to any cause, will, of course, short circuit the field resistance with this device. The line contactor is fitted with the usual overload relay, set to operate at a greater current than SS, as a protection against overloads too heavy to be eliminated by strengthening the field.

Series Contactors.

These may be used only as automatic accelerating contactors, the actuating coil being energized by the line current. The operation may be understood from the elementary diagram (Fig. 80), which represents the circuits necessary to cut out automatically one section of a starting resistance. The actuating coil C is connected in series with the motor armature. Its core forms a pole face at the top to attract the cast-iron armature A across the air-gap G1. This armature is pivoted at P and carries the moving contact T and the vertical iron strip L. The lower end of L forms a pole face which is attracted across the lower end of the air-gap G2 by the horizontal iron extension E at the bottom of the coil C. The attraction across the upper air-gap G1 tends to close the contacts at T and the attraction across the lower gap G2 tends to hold the contacts open. A brass screw at gap G2 forms a stop for the strip L and regulates the length of the air-gap. This adjustment determines the current value at which the contactor will close. The weights of the moving parts are so distributed that the contacts are normally open, the strip L resting against the stop at G2. A vertical iron strip S, of limited cross-section, connects the strip E to the arm A at the pivot P. This strip S forms a magnetic shunt to the lower air-gap G2, and there are two paths for the flux created by the coil. The magnetic circuit is represented by dot and dash lines in Fig. 80, which show two parallel paths, one through L and across

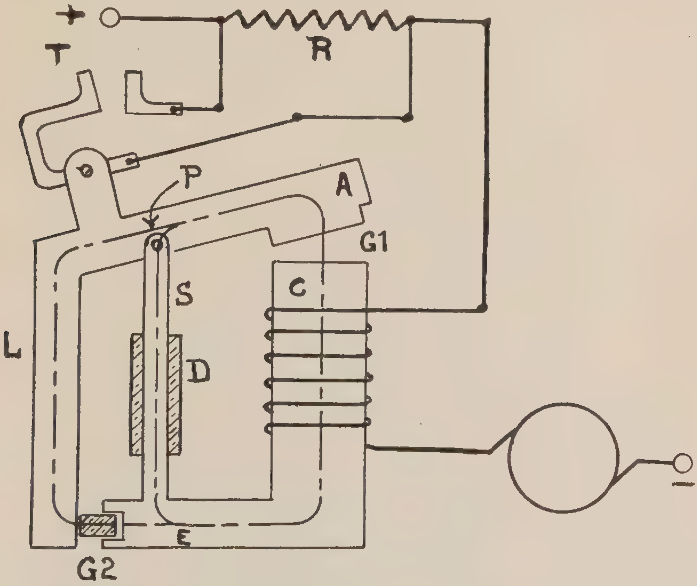


FIG. 80.—Elementary Diagram of Series Contactor.

the Gap G2, and the other through S. The strip S is encircled with a copper band D.

Operation.—When the motor circuit is closed, current flows through the starting resistance R, around coil C, to the motor, to the negative line. The flux set up by the coil C follows the magnetic circuit indicated in Fig. 80. This flux is very strong on account of the heavy starting current. Its attraction across the short gap G2 is stronger than across the long gap G1, and the contact T is held open. As the current in C decreases on account of the increasing back E. M. F. of the motor, the flux across G2 becomes less. The flux through S also decreases, but at a less rapid rate, because S is saturated, which causes the reluctance through S to remain practically constant while the reluctance through G2 increases. The flux across G1, being the sum of the flux across G2 and the flux through S, decreases less rapidly than that across G2. When the current falls to the adjusted closing value, the attraction across G2 becomes less than that across G1, and the contact T closes. This short circuits the starting resistance R.

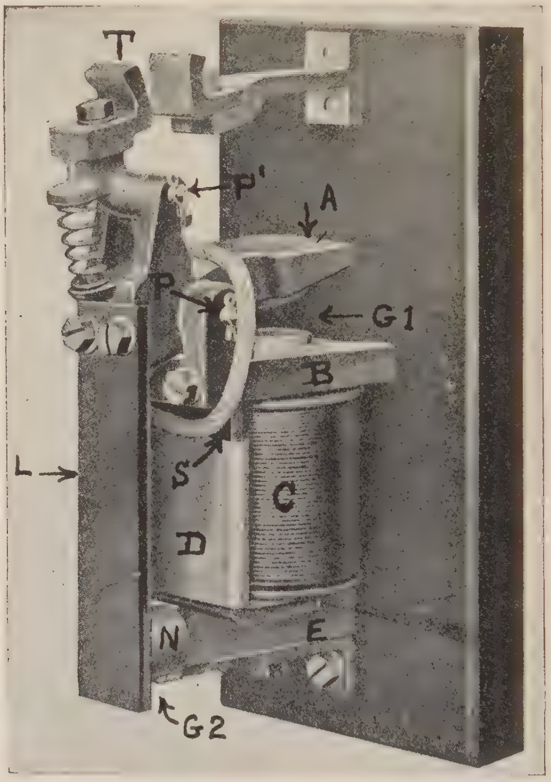


FIG. 81.—Series Contactor. Gen. Elec. Co.

To make sure that the contactor will not close when the current is first turned on the motor, and has not had time to rise to its normal value, the magnetic shunt S is encircled by the copper band D. As the flux is increasing inside this band, it generates an E. M. F. in the copper which causes eddy currents to flow. These induced currents oppose the action that created them; that is, the flux in S. This action causes most of the flux to be forced across the gap G2 while the current is rising, thereby assuring sufficient attraction across G2 to hold the contactor open.

The series contactor will not open on overload. It is evident from Fig. 80 that it will operate as a no-voltage release to the extent of cutting in the starting resistance. Any number may be used to cut out sections of starting resistance in sequence.

General Electric Company's Series Contactor.—Fig. 81 shows the actual construction of the series contactor. The various parts are lettered as in the elementary diagram in Fig. 80. The block B (Fig. 81) that supports the coil is of non-magnetic material. N is a thumb nut for adjusting the brass stop screw at G2. The moving contact T is pivoted at P′, and firm closure of the contacts is assured by the small helical spring. The flexible wire is the lead to contact T. It is arranged in the same plane as the pivot P in order that it may not oppose the motion of the moving parts.

BRAKES.

Dynamic Brakes.—A motor is said to have a dynamic brake when the connections are so arranged that motion is retarded by generator action in the motor. The essential requirements for a dynamic brake are excitation of the motor's field and an external circuit from brush to brush. The Day system of motor control is based on this principle, and many variations of the Day System are used in the Navy, several of them being explained in detail in the chapters on "Applications of Motors." The dynamic brake is very often used with turret-turning motors and the like, where there exists a possibility of movement of the load when the motor is dead. For this purpose connections are arranged so that the field is excited when the controller is in the " off " position, and the brushes are connected through very low resistance. If the load then starts to turn the motor, the heavy current generated greatly retards the speed.

Solenoid Brakes.—Solenoid (or friction) brakes are designed to stop a motor in case of emergency. These brakes consist of a friction device of some kind which is held in engagement by a spring or weight with sufficient force to bring the moving motor to a gradual but quick stop. The brake is released by a solenoid which operates against the tension of the spring. Solenoid brakes are used only to stop the motor, never to retard its speed. They are classified in accordance with the type of friction member used as **band, cone** and **disc** brakes.

The Solenoid Band Brake.—The band-brake type consists essentially of the following parts: wheel, band, solenoid, and lever, and is shown in detail in Fig. 82. The wheel is a flat-faced pulley located on the armature shaft. The brake band consists of sheet steel lined with leather and surrounds the wheel, one end being attached to a lever near the end upon which it pivots, and the other end of the band secures to the outside of the solenoid case. On the free end of the lever is attached the solenoid plunger which ordinarily acts under gravity, thus drawing the band tightly around the wheel and preventing the armature from turning. When this weight is lifted the band is released and the wheel turns freely.

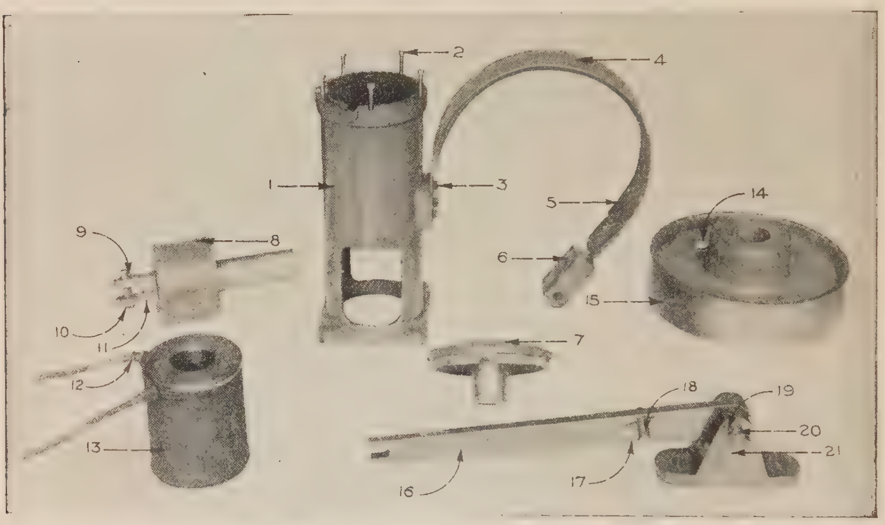


FIG. 82.—CB-17 Motor. Detailed Parts of Band Brake. Gen. Elec. Co.

The solenoid consists of a spool the core of which is attached to the brake lever and lifts the same when energized. Consequently, when a current is passing through the coils, due to the operation of the controller, the brake is automatically released and remains open until the circuit is broken.

The brake should always be kept free to move, as it is the ultimate safety device in case other means of control fail.

Electric Cone Brake.—A brake of this type is shown built into the right-hand end bonnet of the motor illustrated in Fig. 84. The springs press against a steel disc, feather keyed to the frame and free to move along the shaft. This disc in turn presses against a ring keyed to the shaft and free to move along it. The ring bears against a conical surface on the end bonnet.

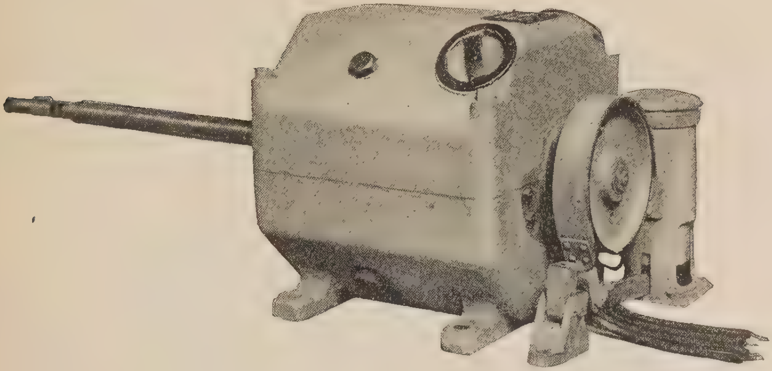


FIG. 83.—Assembled Solenoid Band Brake. Gen. Elec. Co.

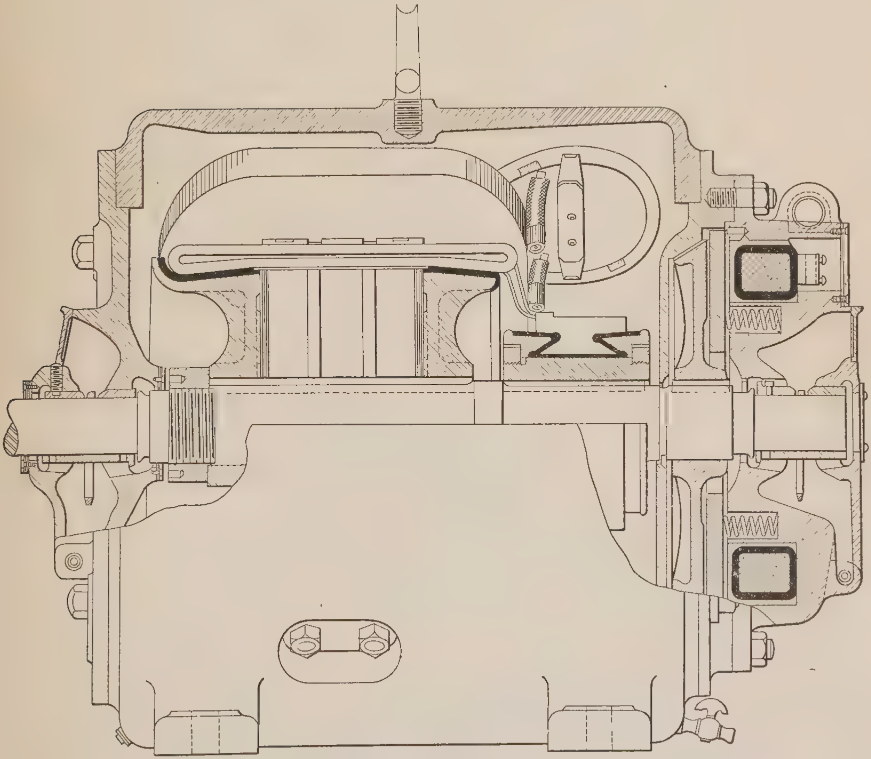


FIG. 84.—Assembly of CB-27 Motor with EC-104 Brake. Gen. Elec. Co.

The friction surfaces are at the contact between ring and cone and at the contact between ring and disc. The solenoid winding is shown enclosed in heavy lines. The coil is excited whenever current is turned on the motor and attracts the disc, thus releasing the brake. Should the circuit breakers blow, or current fail for some other reason, the solenoid is de-energized and the brake automatically locks the motor. The cone brake is suitable for motors hoisting moderate loads, the one illustrated being for a chain ammunition hoist. If a more powerful braking effect is required, the disc type is used.

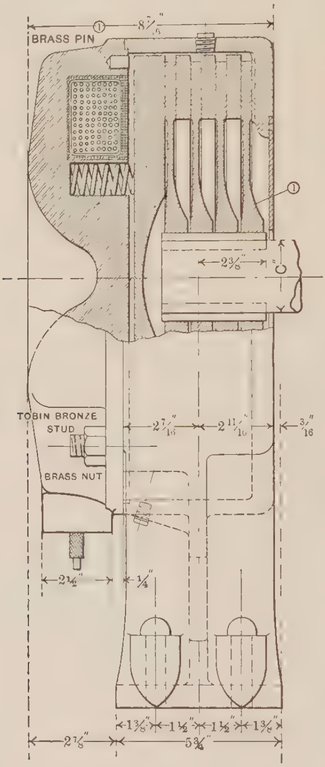


FIG. 85.—ED-108, Form A Disk Brake. Gen. Elec. Co.

The Disc Brake.—The automatic disc brake shown in section in Fig. 85, and in exploded view in Fig. 86, consists of a cast-steel frame, an electromagnet, steel armature, discs, annular rings and springs.

Frame.—The frame is a steel casting consisting of a base carrying a barrel of sufficient depth to receive the discs, rings and armature. Four tobin bronze studs provide a support for the electromagnet, and there are two keyways, diametrically opposite, to receive the keys on which the annular rings

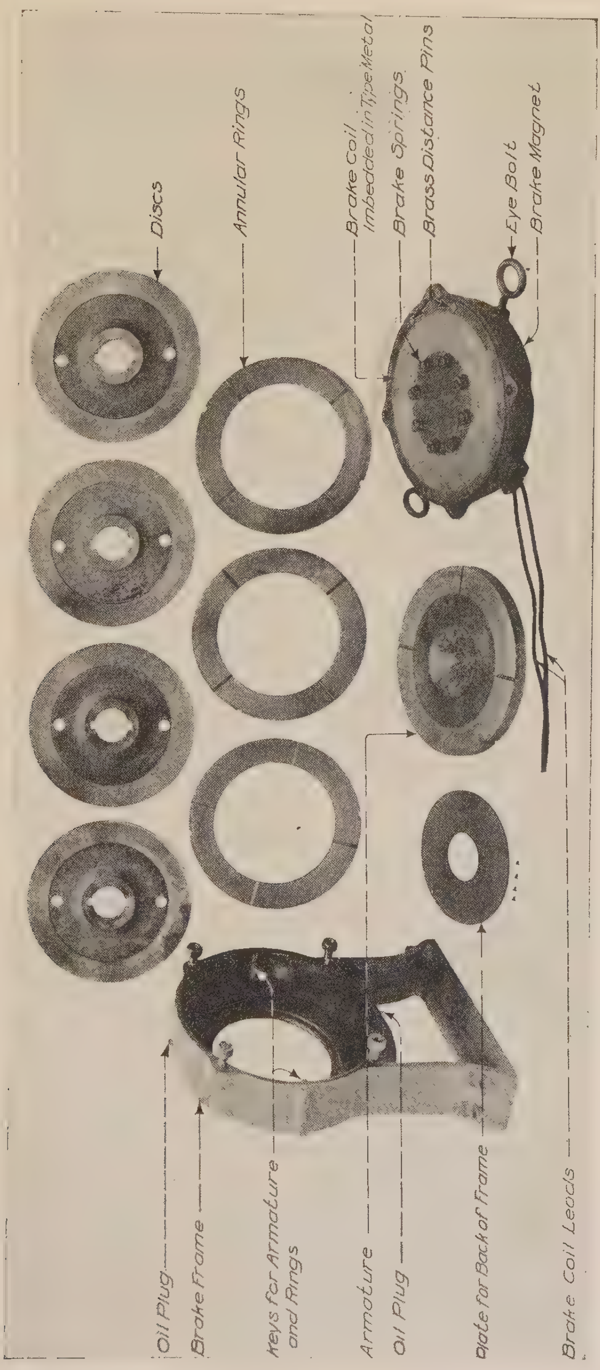

Discs
Annular Rings
Brake Coil Imbedded in Type Metal
Brake Springs
Brass Distance Pins
Eye Bolt
Brake Magnet
Oil Plug
Brake Frame
Keys for Armature and Rings
Armature
Oil Plug
Plate for Back of Frame
Brake Coil Leads

FIG. 86.—ED-108 Disc Brake. Exploded View.

have an easy sliding fit. A hole is cast in the back of this barrel through which the extended motor armature shaft projects.

Electromagnet.—The electromagnet is a steel casting with suitable lugs which support it on the frame. Brass nuts draw the magnet to the frame, making a watertight joint.

A coil slot, annular in form, is provided in the casting in which the winding is secured by type metal.

Suitable spring pockets equally spaced are drilled to receive the helical compression springs.

Armature.—The armature is a steel disc of a sufficient cross-section to carry the magnetic flux without excessive leakage. Four tobin bronze pins are tapped into the armature and project into recesses in the magnet. This construction keeps the armature from rotating while permitting easy motion parallel with the motor shaft.

Annular Rings.—The rings are of cast iron and have a sliding fit on the keys in the frame, which prevent their rotation.

The outside diameter of the rings is slightly less than the inside of the barrel. The inside diameter is carried out to a point where the friction is most advantageous and yet provides a sufficient cross-section to insure against an excessive wear or heating.

Suitable oil slots are provided to secure a uniform lubrication.

Discs.—The discs are of bronze and have hubs which are keyed to the motor shaft.

These discs have an easy motion parallel with the shaft but being keyed thereto must revolve with it.

Holes in the discs relieve atmospheric pressure and add to the convenience of removing the discs from the shaft.

The outside diameter of the discs is slightly less than that of the rings, to secure a clearance from the keys in the frame. The width of the friction face is thus the difference in radius between the outside of the disc and the inside of the ring.

Compression Springs.—The springs are helical in form and are wound of the best spring steel, copper plated. They resist the maximum compression without permanent set or injury.

Coil.—The winding consists of insulated copper wire, form wound, and wrapped with four thicknesses of varnished cambric and two thicknesses of linen binding.

The ends of the coil are soldered to terminals located in a watertight connection box in the magnet. The connection box is made watertight where the brake leads are brought through.

The inner rear of the frame is finished to a suitable diameter and thus becomes a friction face. Adjacent to it is a bronze disc keyed to the armature shaft, then an annular ring keyed to the frame, then another disc keyed to the armature shaft and thus throughout the series. Each ring is keyed to the frame and its adjacent disc to the motor shaft.

The electrical connections are so arranged in the controller that the motor circuits are simultaneously made with the brake coil circuit.

Thus when the controller is thrown on the first position the brake coil energizes the magnet, which draws the steel armature disc toward it, at the same time compressing the helical springs. Thus all pressure on the friction faces of the discs is relieved and the motor starts readily.

There is a sufficient clearance provided between each set of friction faces to reduce the running friction in the brake to a minimum. Lubrication of these surfaces is provided by an oil hole in the top of the frame and a drain hole in the bottom which permits a change of oil. Best operation is obtained with a minimum amount of lubrication.

When the controller is turned to the "off" position the brake coil circuit is opened and the springs immediately force the armature disc against the bronze disc keyed to the shaft and thus the pressure is transmitted to all the friction faces. In coming to rest the armature shaft must carry the discs keyed to it against the friction of all the rings keyed to the frame, the friction face of the frame itself and the friction face of the brake armature. The spring pressure is sufficient to bring the motor armature quickly to a state of rest and yet not injure the friction faces of the discs or rings.

CHAPTER V.

CONTROLLING APPLIANCES.

Controlling appliances consist of apparatus for starting, stopping, reversing and controlling the speed of motors, with the necessary safety devices for the protection of motors and circuits.

Controller is the apparatus for making and changing electrical connections between the main supply lines and motors.

Controlling appliances used in the naval service are in general of three types:

1. Panel type.
2. Drum type.
3. Contactor type.

Small motors requiring less than 10 amperes current, which can be safely started by throwing directly on the line without previous acceleration, may be furnished only with a fused starting switch suitably enclosed.

Wiring Diagrams.—Wiring diagrams showing the leads and connections of circuits will be frequently used in this chapter. They indicate the various appliances, in their relative positions, and the electrical connections and leads.

Elementary wiring diagrams show the electrical connections and circuits, without regard to the position of the appliances, but with a view to making the electrical connections clear. Elementary diagrams should be made by the student to assist in a clear understanding of the principles involved.

PANEL-TYPE CONTROLLERS.

A panel-type controller consists of a smooth, flat panel, with the protective devices and control apparatus mounted on the face and the resistance mounted on the back. In the types used in the naval service, this self-contained unit, including all the parts that make up the "controlling appliance," is usually mounted in a case, watertight or non-watertight, as may be required.

The panel-type controller is used for starting and regulating the speed of continuous running shunt or compound-wound motors of 12 horsepower or less. It is not suitable for handling large currents, or for frequent changes of speed, starting and stopping. It is compact, and easily mounted.

WATERTIGHT PANEL (Fig. 87).—The panel for a watertight controller is enclosed in a heavy, rugged, watertight, flame-proof case containing all the fittings, protective devices, resistances, etc. The case is fitted with suitable hinged covers, fitted with clamping devices, and made watertight by means of rubber gaskets.

The panel is operated, without opening the case, by means of external handles connected to the operating arms by levers or rods passing through composition stuffing boxes in the case. The operating parts are designed to reduce the number of these external handles to a minimum. Marks and label plates placed on the case indicate the position of the operating arms.

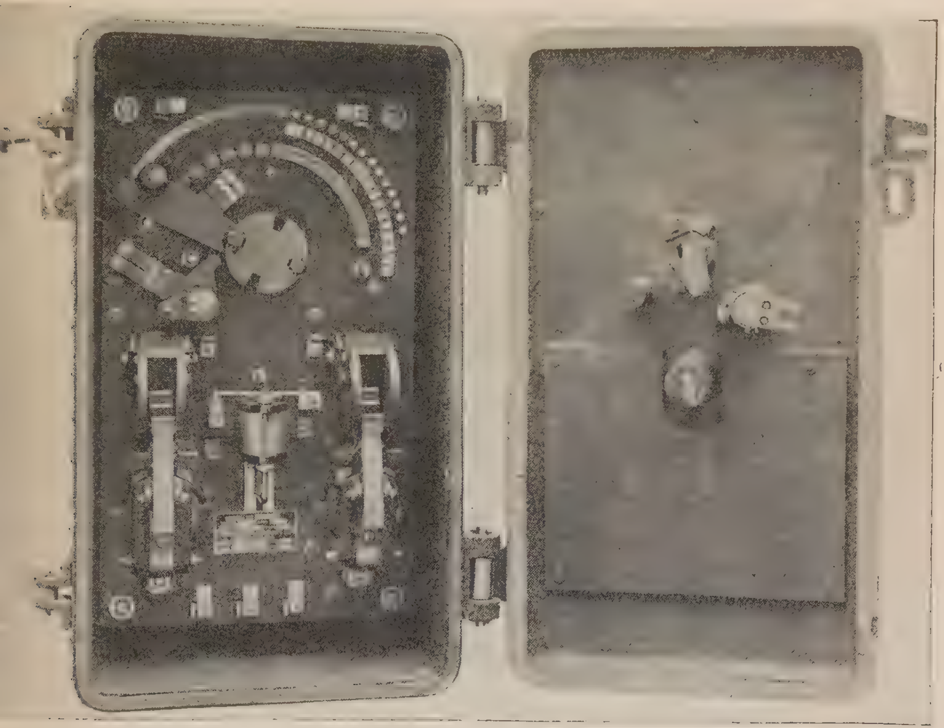


FIG. 87.—Watertight Panel Controller.

The external handles are provided with indicating pointers, and are detachable to prevent unauthorized handling.

NON-WATERTIGHT PANEL (Fig. 88).—The panel for a non-watertight controller, under U. S. Navy Specifications, is mounted in a rigid metal box. usually of sheet iron with solid top, bottom, back plates, and side plates, and hinged doors on the front that enclose and protect the panel. When not required to be flame proof the side plates are perforated. Resistances are mounted on the back of the panel.

The **requirements** to be fulfilled by a panel-type controller are as follows:

1. The starting arm must be so arranged that if it is left on any starting contact and the hand of the operator removed the circuit will be interrupted and the motor will stop.

2. The starting resistance must not be left in series with the shunt field in any running position.

3. Provisions will be made to prevent objectionable arcing at the first starting contact.

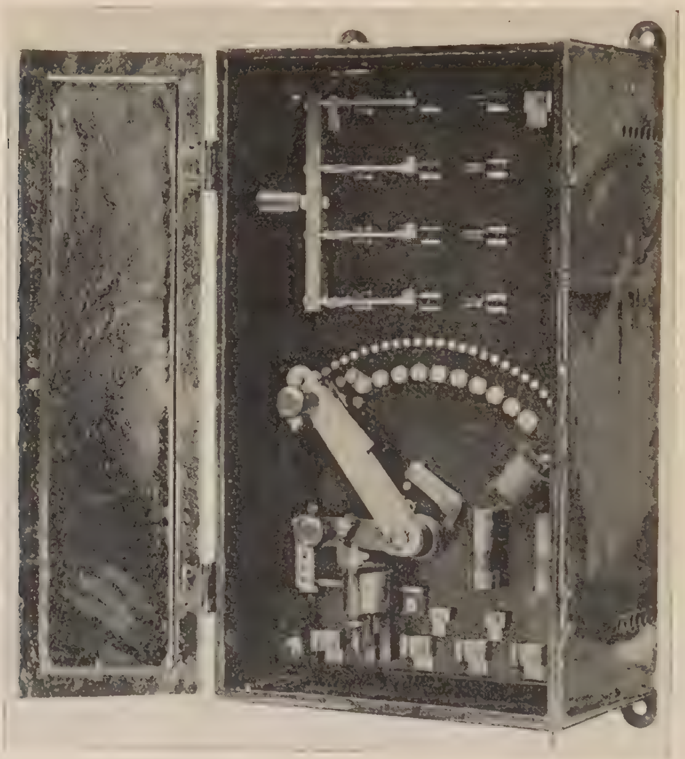


FIG. 88.—Non-watertight Panel Controller.

4. If field regulation is provided for, a sufficient number of field regulating points will be provided to give a smooth and even speed control, over the required range, and the lever will be held securely in any of these positions. This lever will be so arranged that the motor cannot be started with weakened field.

5. Upon interrupting the circuit, the shunt field must be so connected that inductive discharge will be absorbed by the armature, or a separate field discharge resistance must be furnished.

6. The field must not be energized with the starting arm in the "off" position.

7. The "no-voltage release" must operate to cut off all current from the motor in case of a 90 per cent reduction of voltage.

8. The overload device must protect the motor and panel under any possible condition of overload.

In studying the controllers described, these requirements should be borne in mind, and the manner in which they have been met should be clearly understood.

Starting Panel (General Electric Co.).—This is a simple form of panel-type controller. The wiring diagram is shown in Fig. 89.

Essential Parts of Panel-Type Controller.—The essential parts for any panel-type controller will be described, using Fig. 89 for reference.

1. PANEL.—Flat surface of smooth, durable, insulating material (usually slate or impregnated asbestos lumber) on which the various appliances are mounted.

2. LINE SWITCH (S, Fig. 89).—The line switch is in the supply line circuit, and opens one or both sides of the line. In this case a double-pole, double-arm, circuit breaker serves the purpose of both line switch and "overload device."

3. FUSES (Fig. 89).—The fuses, also in the supply line circuit, are enclosed fuses and have been fully described.

4. TERMINALS (L, LL, F & A, FF, AA, Fig. 89).—The terminals consist of lugs secured to studs on the panel, to which the various leads can be readily connected.

5. CONTACTS (1, 2, 3, 4, etc., Fig. 89).—The contacts are blocks of conducting material on the face of the panel that project through the panel and are connected to sections of the resistance behind the panel.

6. RESISTANCES.—The resistances, behind the panel, are arranged to meet the special requirements of the individual panel.

7. STARTING ARM (S. A., Fig. 89).—In this case the starting arm is a conductor. It is mounted on a shaft at one end and at the other end carries a contact brush that bears on the different contacts as the arm is moved. The shaft is connected to the supply line. The arm thus makes electrical connection from the line to the particular contact on which it rests. A spring around the shaft tends to throw the arm back to the "off" position unless it is held by the operator's hand or the magnet described below. The lug C is held, in the position shown, by a spring. It can be moved to the right against this spring. The starting arm is moved from the left to the right, makes connections energizing the field, and makes the armature circuit, through the resistance, then gradually cuts out that resistance.

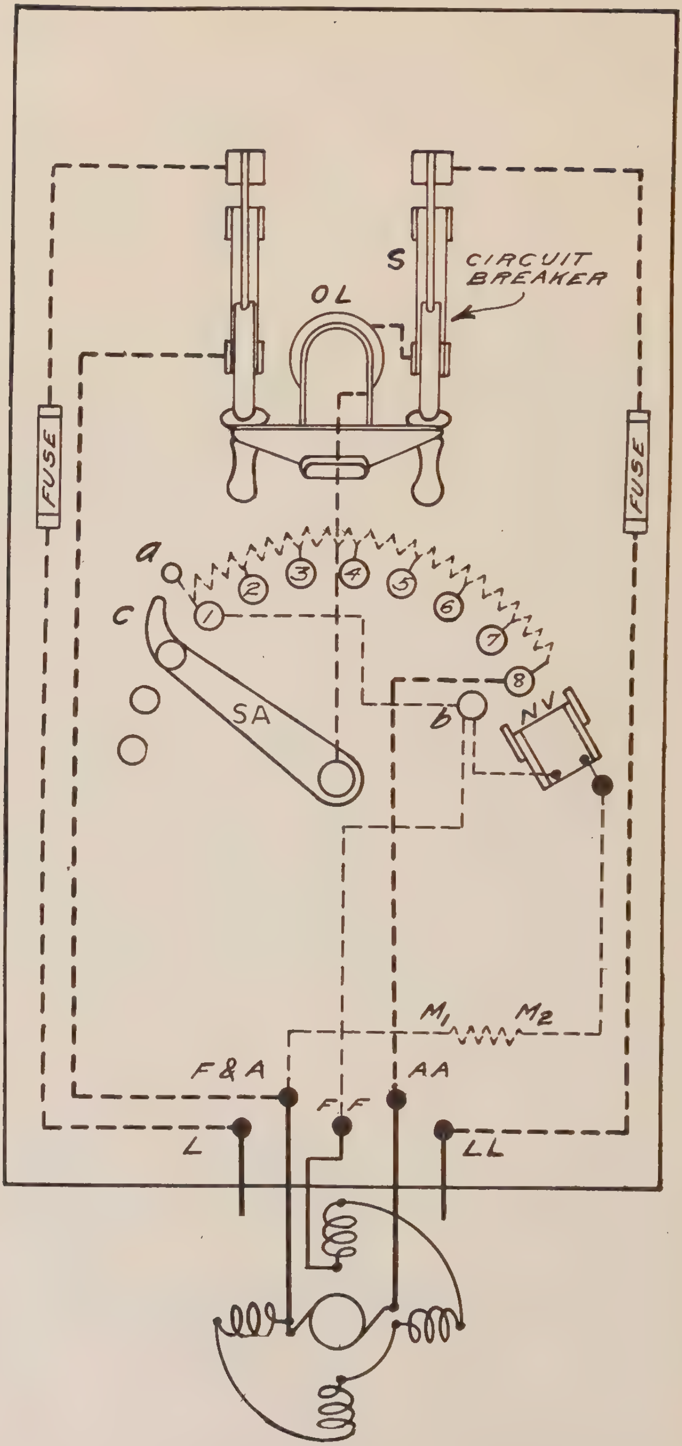

CIRCUIT BREAKER
S
OL
FUSE
FUSE
a
c
1
2
3
4
5
6
7
8
SA
b
NV
M1
M2
F & A
AA
F F
L
LL

Fig. 89.—Starting Panel. Type CR, Form P. Gen. Elec. Co.

8. REGULATING ARM.—Used in panels designed for speed control and not shown here.

9. NO-VOLTAGE RELEASE (NV, Fig. 89).—The no-voltage release is a device for breaking the circuit and stopping the motor when the E. M. F. fails. The shunt field connection runs from contact 1 to *b* to the shunt field. A shunt takes off at *b*, leads through the magnet NV, resistance M_1M_2, to terminal F & A. When the starting arm is moved to the right so that the arm brings up against the magnet NV, that magnet, when energized, holds the arm in that position against the force of the spring around its shaft. If NV becomes demagnetized as by failure of the field current, its armature will no longer attract the arm, and the spring will throw it back to the "off" position breaking the armature circuit and stopping the motor.

10. OVERLOAD DEVICE (OL, Fig. 89).—This device is for the purpose of breaking the circuit and stopping the motor in case of overload, affording protection to the motor and circuits. The magnet coil OL is in series with the line, and, in case of overload, trips the circuit breaker which opens the main circuit. As the motor slows down the no-voltage magnet releases and the arm is returned to the starting position.

CONNECTIONS.—The line current leads from LL through fuse to one arm and overload coil of circuit breaker, starting arm, resistance in series, to terminal AA; through armature, to F & A; through other arm of circuit breaker, to fuse, to L.

The shunt-field connection is taken off at contact 1, to connection *b*, terminal FF; through motor shunt field to armature connection.

When the circuit is broken, as by circuit breaker opening, the armature is connected across the shunt field, thus absorbing the inductive discharge.

OPERATION:

To Start.—

1. Close the switches.

2. Move the starting arm slowly to the right. The lug C first makes contact with *a*, energizing the field and the armature. This lug operates against the spring as the arm is moved forward, making firm contact with *a*, thus preventing arcing. At this point all the armature resistance is in. Move the arm slowly to right over the contacts 1, 2, 3, etc. The motor should start to revolve by the time the arm is on contact 4; if it does not, trip the circuit breaker and ascertain the trouble. First make sure the voltage is across the mains, and then make a close examination into all the connections that are liable to become loose or displaced. As soon as the motor begins to revolve, move the starting arm slowly from one contact point to the next, until it has reached the "full-on" position, at which point it will be firmly

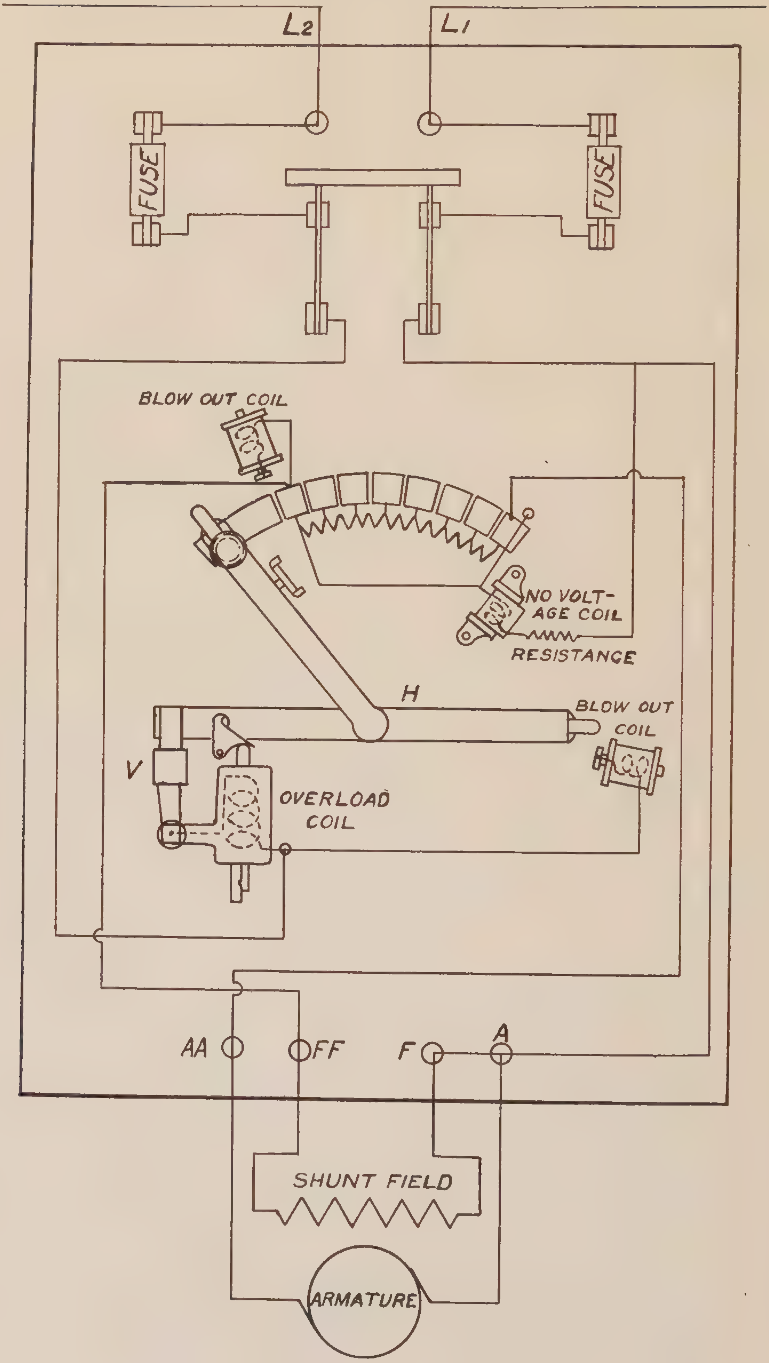

L2
L1
FUSE
FUSE
BLOW OUT COIL
NO VOLTAGE COIL
RESISTANCE
H
BLOW OUT COIL
V
OVERLOAD COIL
AA
FF
F
A
SHUNT FIELD
ARMATURE

FIG. 90.—Starting Panel. Ward-Leonard Co.

retained by the small magnet. At this point the arm makes contact with stud *b*, cutting the starting resistance out of the field circuit.

To Stop.—Trip the circuit breaker, and allow the arm to take care of itself. It will not be immediately released, but will be held in place until the motor slows down when it will fly back to the "off" position. Never attempt to stop the motor by forcing the arm to the off position; always open the main line switch, or trip the circuit breaker. (These are frequently separate.)

Starting Panel, Ward-Leonard Co. (Fig. 90).—This panel differs from the General Electric Co. panel described above in two respects.

1. Overload device.
2. Method of preventing arcing at first contact.

OVERLOAD DEVICE.—The overload device consists of the "*overload coil*" and the "*tripping device.*" This device is composed of a *horizontal arm* H, and *vertical arm* V.

The *horizontal arm* is mounted on the same shaft as the starting arm. It must be pressed down to the left against a spring, to make contact with the vertical arm. When in contact the latch shown engages and holds it. If the horizontal arm is pressed down with the starting arm in any other than the "off" position the solenoid will be energized and the latch will not engage. The armature current leads from the line L_2 through fuse, switch, overload coil, to the vertical arm, horizontal arm, starting arm, armature resistance, armature, to line L_1. In case of "overload" the overload coil raises the plunger, trips the latch, the horizontal arm flies up due to the action of the spring, breaking the armature circuit.

METHOD OF PREVENTING ARCING.—There are two "blow-out coils" as shown. In starting, the starting arm makes contact first with the plunger on the blow-out coil. A strong magnetic field, formed between the tip on the starting arm and the magnet, blows out the arc. The plunger is pressed out by a spring, insuring firm contact.

When connection between V and H is broken, connection is made with the blow-out coil through the other end of H where the final break is made. A strong magnetic field is formed which operates to blow out the arc.

Starting and Regulating Panel (General Electric Co., Type CR, Form M2).—Figs. 91 and 92 show a starting and regulating panel manufactured by the General Electric Co. This differs from the starting panels described, in addition of REGULATING ARM (R) and FIELD RESISTANCE (behind the board, indicated in the diagram) and corresponding CONTACTS 1 to 12.

CONNECTIONS.—The line current leads from L_2 through fuse and circuit breaker, to starting arm. When the arm is in running position, on contact 8, the armature current leads through starting arm to contact 8, to terminal AA, to armature, to F & A, to circuit breaker, fuse, to L_1. Shunt-

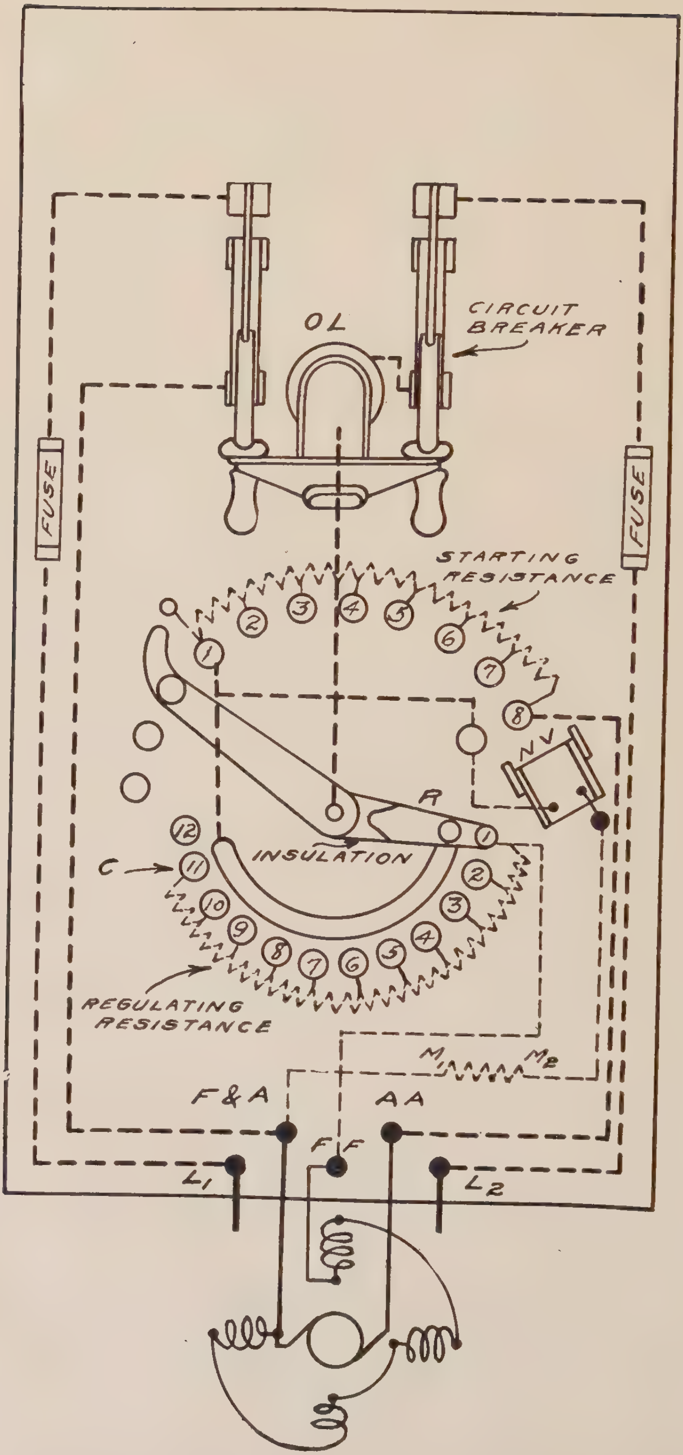

CIRCUIT BREAKER
OL
FUSE
FUSE
STARTING RESISTANCE
1
2
3
4
5
6
7
8
NV
R
INSULATION
C
12
11
10
9
8
7
6
5
4
3
2
1
REGULATING RESISTANCE
M1
M2
F&A
AA
F
F
L1
L2

FIG. 91.—Starting and Regulating Panel Type CR, Form M4. Gen. Elec. Co.

field current leads from starting arm to contact 1 of starting resistance, to contact ring, to regulating arm, through field resistance, to field contact 1, to FF, through motor field, to armature connection on motor. The "no-voltage" shunt leads from contact 1 through no-voltage magnet, to connection F & A.

REGULATING ARM.—This arm R carries two brushes. One moves over the contact ring, and the other over the field resistance contacts. These brushes are electrically connected, and the outer end of the arm is insulated from the inner end. As it is moved over the contacts, it cuts resistance into, or out of the field circuit. The regulating arm is interlocked with the starting arm so that the motor cannot be started except when the regulating arm is in the position shown—all field resistance cut out. (See panel of this type in laboratory.)

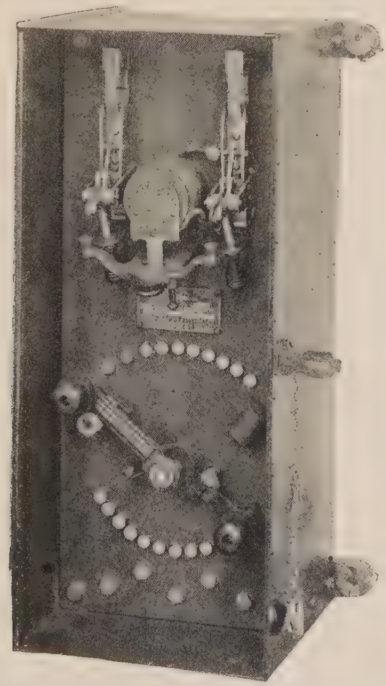


FIG. 92.—Panel Type CR, Form M4 (Doors Removed).

OPERATION:

To Start.—As with starting panel. Regulating arm must be on contact 1.

To Regulate.—Move field regulating arm to right (clockwise) to increase speed, to left (counter clockwise) to decrease speed.

To Stop.—As with starting panel.

Starting and Regulating Panel (General Electric Co., Type USB, Form M2, Fig. 93).—This panel differs from those previously shown, mainly in the fact that there is an automatic contactor in the main line which also operates as a no-voltage release.

CONTACTOR.—Switch S being closed, current leads from line LL through switch S, to overload coil, and to arm H. When arm H is moved to make contact marked "solenoid switch holding resistance," part of the current then flows from arm H to overload switch S′, through contactor solenoid, and to line L. This solenoid then attracts the contactor plunger, closing the circuit through armature and field to line L.

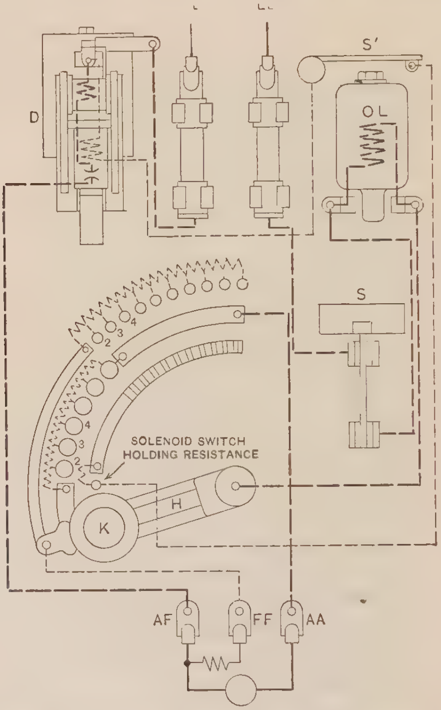


FIG. 93.—Starting and Regulating Panel Type USB, Form M2. Gen. Elec. Co.

OPERATING ARM.—A single arm H serves both for starting and regulating. This arm has a knob K, which can be pressed down against a spring. When K is pressed down, it makes contact between H and inner contact ring. This inner contact ring is depressed, in all starting positions of arm H, so that if pressure on K is released, this contact is broken. In any running position of arm H, contact ring is elevated and notched, and K does not need to be held down, but rests in any notch and contact remains unbroken. Arm H also has two contact brushes, the inner of which makes connection with (middle) starting resistance contacts and contact segment (the latter for running position of arm); and the outer brush with (outer) field contact segment and field resistance contacts (the former for starting, the latter for speed regulation).

OPERATION.—It is obvious that as button K is pressed and arm H is moved to the right, contactor closes, field becomes fully energized, and current flows through armature and all armature starting resistance. As arm is moved to the right, starting resistance is cut out until motor has full-line voltage across armature. Knob K then rests in first notch, and may be released. Further rotation of arm cuts in field resistance, and speeds up motor.

NO-VOLTAGE RELEASE.—If line voltage fails, the solenoid becomes de-energized and the contactor drops. If line voltage is again applied, contactor will not close, as current flows through small resistance marked "solenoid switch holding resistance," and this current, while large enough to *hold* contactor closed, is too small to *lift* it. Circuit thus remains open until the arm is returned to first starting position, in which this small resistance is short circuited, and contactor is lifted once more. This method of insuring that the motor cannot be started with the arm in any other than the starting position is used in a number of types of controllers.

OVERLOAD.—In case of overload, a plunger in overload coil is lifted and opens switch S′, and contactor drops. The arm must be returned to first starting position as before.

Starting and Regulating Panel (Cutler-Hammer Mfg. Co., non-watertight, flame-proof, Fig. 94; see also Fig. 88).—This panel is mounted in a flame-proof casing with doors that must be opened for operation. There are two arms for starting and regulating.

STARTING ARM.—The starting arm SA is the shorter of the two arms, and operates against a spring around the shaft, tending to throw it back to the "off" position. There is a projecting lug on its right-hand edge, so that the regulating arm, when moved to the right, brings up against the lug and carries the starting arm with it. Also if the starting arm is thrown to the left by the action of the spring, when the regulating arm is in any intermediate position, the lug strikes the regulating arm and both arms are carried back to the starting position. The starting arm carries two brushes, one that moves over the armature resistance contacts 1 to 8, and the other moving over the contact ring C.

REGULATING ARM.—The regulating arm RA is mounted on the same shaft as the starting arm and is electrically connected with it. It carries a brush at the outer end that moves over the field resistance contacts 24 to 11.

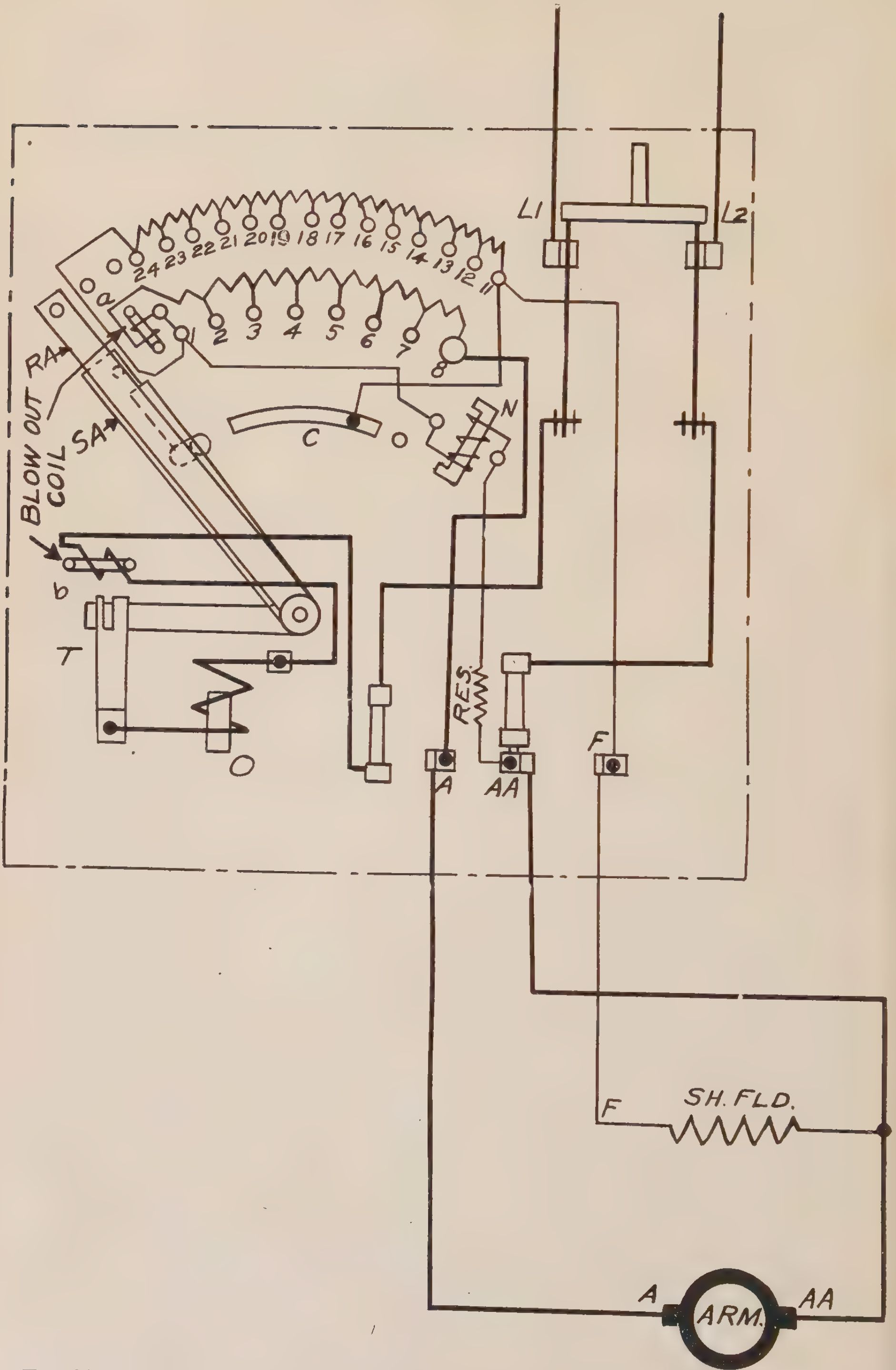

L1
L2
24
23
22
21
20
19
18
17
16
15
14
13
12
11
a
1
2
3
4
5
6
7
8
RA
BLOW OUT COIL
SA
C
O
N
b
T
O
RES.
A
AA
F
F
SH. FLD.
A
ARM.
AA

Fig. 94.—Starting and Regulating Panel, Ventilating Fans. Non-Watertight. Cutler-Hammer Co.

OVERLOAD DEVICE.—The overload device consists of the overload coil O and the tripping device T. Contact between the vertical and horizontal arms of the tripping device furnishes a path for the line current to the starting arm. To make this contact the horizontal arm must be pressed down against a spring until it engages a latch that holds it in contact with the vertical arm.

The vertical arm is mechanically interlocked with the starting arm so that the latch will not engage unless the starting arm is in the "off" position. In case of overload the overload solenoid operates a plunger that trips the latch, releasing the horizontal arm, breaking the contact between the two arms.

The "blow-out" coils and their operation have already been explained.

OPERATION:

To Start.—The regulating arm is moved to the right slowly carrying the starting arm with it. In the first position the starting arm closes the armature circuit through all the starting resistance, and closes the field circuit through the contact ring C—contact 11—to the field, all field resistance short circuited. The armature resistance is cut out as the arm is moved to the right, the field remaining at full strength. In the "full-on" position all armature resistance is out, and the starting arm brush has moved off the contact ring C. The field circuit is then made through regulating arm, to contact 11, to field.

To Regulate.—The regulating arm is moved to the left, throwing resistance into the field circuit.

To Stop.—Open switch or trip overload device. In either case the armature and field are in series through starting resistance, connection from contact 1 to contact 24, and field regulating resistance, absorbing the inductive discharge.

Starting and Regulating Panels (Cutler-Hammer Mfg. Co., watertight). Wiring diagram for this panel is shown in Fig. 95.

Fig. 87 shows this panel as mounted.

The essential features present some differences from the panels already described, and the requirements are met in a different way. One arm is used for both starting and regulating. This is a watertight, flame-proof panel and is operated without opening the panel. Removable handles on the outside of the case operate through levers both the starting and the auxiliary arms. The shafts of these levers are made watertight by means of stuffing boxes in the cover.

OPERATING ARM.—This arm is a conductor and carries two brushes that make connection, respectively, with the two arcs of contact rings and contacts. There is a projection secured to the arm with brushes that, in the starting position, make connection between the contacts *a* and *b*. The two circles to

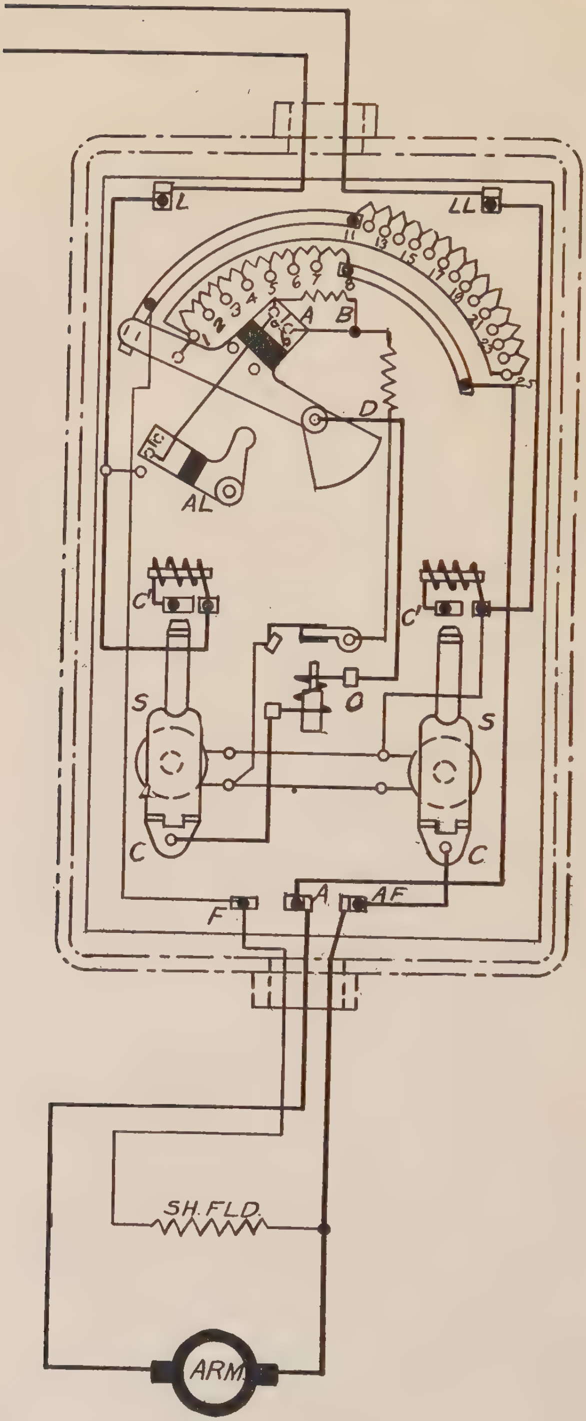

L
LL
1
2
3
4
5
6
7
8
11
13
15
17
19
21
23
25
A
B
D
AL
C'
C'
S
S
O
C
C
F
A
AF
SH.FLD.
ARM

FIG. 95.—Starting and Regulating Panel. Ventilating Fans. Watertight. Cutler-Hammer Co.

the left of *a* and *b* are the studs that secure the projection to the arm and do not make contact. The heavy black lines on the operating arm and the auxiliary arm represent insulation.

CLAPPER-TYPE SWITCHES.—There are two of these, S, S, actuated by solenoids. When the solenoids are energized, the switches make connection between C and C′. The solenoids are energized by an operating circuit. This circuit is taken off the lead from L, to the auxiliary arm AL, to *a*, to *b*, through switch, through solenoids in parallel, to line LL. Sufficient current flows to close the solenoids. When the arm is in any position to the right of that shown, the connection on *a*, *b*, is broken, and the path of the current is through the resistance AB. Sufficient current will flow to hold the switches closed, but not enough to close them, if open. The operating arm must, therefore, be brought back to the starting position to start the motor. Upon failure of voltage the switches will open.

AUXILIARY ARM, AL.—This arm must be held down to the left by hand against a spring to close the operating circuit, while any of the *starting* resistance is in circuit. When the operating arm is on contact 8, all starting resistance out, a mechanical latch engages this lever, and holds it down when the operating arm is in any *running* position.

OVERLOAD DEVICE.—The coil O, in case of overload, actuates a plunger, opening the switch shown above it in the operating circuit, and the clapper-type switches will open. "Blow-out" coils are shown above the switches.

OPERATION:

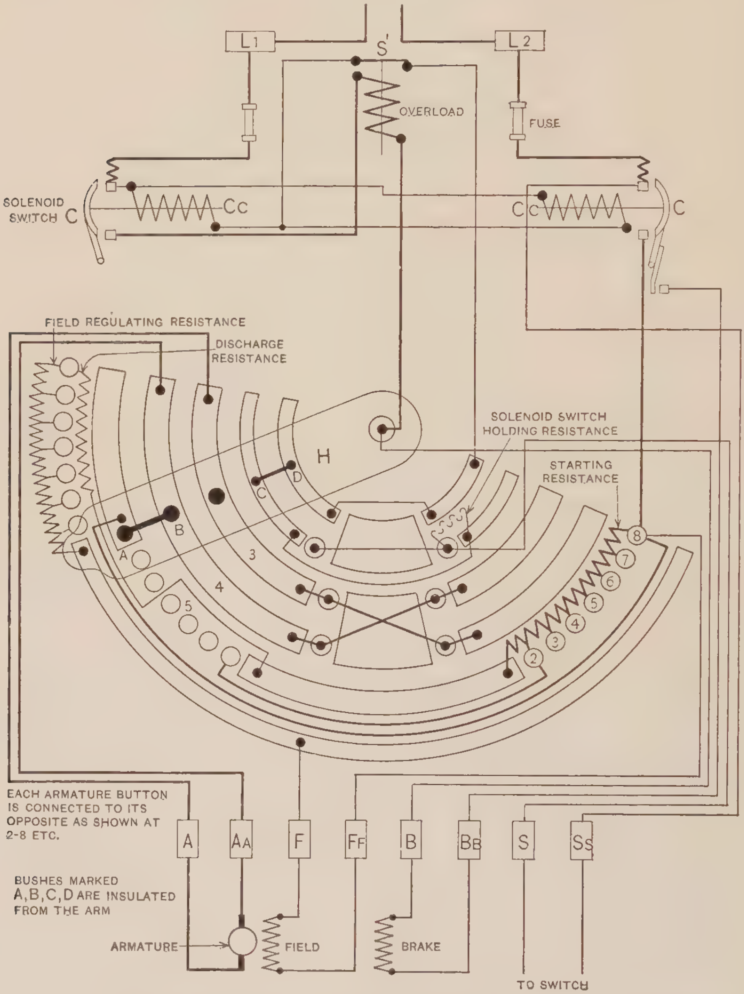
The auxiliary arm is pressed down closing the operating circuit, and the clapper-type switches. The operating arm is moved to the right, gradually cutting out the starting resistance. The auxiliary arm must be held down until all starting resistance is cut out. Further movement of the operating arm throws resistance into field, increasing speed.

When the overload device operates or line switch is opened, the armature and the field are in series with regulating and starting resistances, by means of the connection from contact 1 to 25.

Starting and Regulating Panel, Reversing. (Watertight, flame-proof, General Electric Co.)—Wiring diagram of this panel is shown in Fig. 96.

CONTACTORS.—There are two contactors or solenoid switches which act as main-line switches and circuit breakers in case of "overload" or "no voltage." These switches are closed by an operating circuit whose terminals are on the live side of the contactors.

These contactors consist of a stationary and movable contact; the latter, pivoted at the bottom, is operated by the armature of a vertical solenoid which brings the contacts together with a slight rolling motion which ensures good electrical connection. The contacts are of copper and so operated that the arcing takes place at the tips. When the contacts are in full-closed position the tips are slightly separated by the rolling motion in closing so that a smooth surface is always provided for carrying the current.


L1
S'
L2
OVERLOAD
FUSE
SOLENOID SWITCH C
Cc
C
Cc
C
FIELD REGULATING RESISTANCE
DISCHARGE RESISTANCE
SOLENOID SWITCH HOLDING RESISTANCE
STARTING RESISTANCE
H
D
C
B
A
3
4
5
8
7
6
5
4
3
2
A
AA
F
FF
B
BB
S
SS
ARMATURE
FIELD
BRAKE
TO SWITCH

EACH ARMATURE BUTTON IS CONNECTED TO ITS OPPOSITE AS SHOWN AT 2-8 ETC.

BUSHES MARKED A,B,C,D ARE INSULATED FROM THE ARM

FIG. 96.—Starting, Regulating and Reversing Panel. Watertight. Chain Ammunition Hoist. Gen. Elec. Co.

When the coil circuits are opened, the contacts are forced apart by a spring, quickly rupturing the arc. There is connected in series with the operating circuit a small resistance, marked "solenoid switch holding resistance," which reduces the current to an amount that is sufficient to hold the contacts closed, but is not enough to close them. When starting in either direction the resistance is short circuited by the first contact buttons, thus giving full potential to the coils and closing the contacts. After moving the arm a short distance the resistance is thrown in, reducing the current to the holding value.

OPERATING ARM.—There is one operating arm, H, carrying brushes moving over contact segments and buttons. Brushes A, B, C, D are insulated from the arm and only serve to connect the adjacent rings over which the arm is moving.

OVERLOAD.—The overload device consists of the switch S′ in the operating circuit of the contactors. When the current exceeds a predetermined amount, it is opened by the movement of an adjustable core. Owing to the holding resistance mentioned above the current through the operating circuit is not of sufficient value to lift the contactors and close them, and they can only be closed by returning the arm to the off position and short circuiting this resistance.

The switch (not shown) connected to the terminals, S, Ss, may be located at any convenient place near the hoist and is normally held closed. By opening this switch at any time, the operating circuit is opened and the equipment is dead.

OPERATION.—A reference to the diagrammatic connections will show the method of operation. At the "off" position, the arm H is in its center or vertical position. When the arm is moved in one direction, say to the left, until the arm rests across the row of segments and contacts 5, circuit is made for the operating circuits as follows: from line L_1 through the contactor coils CC, in parallel, across the switch S′, through D, C, and the holding resistance, to S, through the switch to Ss, to line L_2. When this circuit is completed, the contactors C, C close. The main current then flows from line L_1 through the contactor and overload coil to the pivot of the starting arm. From here the current flows to segment 3 through the armature to segment 4, through the connecting brushes BA to the row of contacts 5. These contacts are connected to the ones marked 2, 3, 4, etc., to which the units of starting resistances are connected. Current flows from brush A to contact 2 through the starting resistance and through contactor C to line L_2. As the arm is moved farther to the left the starting resistance is gradually cut out, until the position shown in the figure is reached when all resistance is out.

The field circuit is made from the arm to the outer segment, through the shunt field to the other side of the line at contact 8. As the arm is moved to the left from the position shown, the field resistance is gradually cut in circuit and the speed of the motor is increased.

For reversal of the armature, it is only necessary to move the starting arm in the opposite direction, when an inspection of the connections of segments 3 and 4 will show that the current through the armature is reversed while the field remains as before.

BRAKE.—There is a shunt-wound solenoid brake. The circuit is energized and brake released when the right-hand solenoid switch closes. The circuit is opened and the brake is set when the switch opens.

FRAME.—The frame consists of a cast-iron box with a hinged cover made watertight by rubber packing, and set up with hinged bolts and wing nuts. The panel must be operated from the outside. The operating handle projects through a stuffing box in the cover, and engages with the operating arm when the cover is closed. The top and bottom are cast thick enough to allow tapping and drilling for conduit.

Starting and Regulating Panel, Reversing (Ward-Leonard Co., watertight, flame-proof).—This panel is shown in Fig. 97. It is used for the same purpose as the last panel described. It must be operated without opening the panel. The operation of the starting arm, overload and no voltage is similar to that described for Ward-Leonard starting panel. An arm mounted on the front of the panel projects through and engages the starting arm.

REGULATING ARM.—The regulating arm is mounted on the lower part of the panel and is operated from the outside in the same manner as the starting arm, over a separate set of contacts connecting to the field regulating resistance. There is a mechanical interlock between the starting arm and a boss on the shaft of the regulating arm that acts to prevent the former from being moved while the latter is in any position but that corresponding to the full-field strength.

REVERSING.—The reversing is effected by the middle blades of the four-pole double-throw switch at the top of the panel. Throwing the switch to the lower position reverses the armature current. This switch is operated by a handle on the outside of the panel, on a shaft that projects through the side of the panel.

Starting and Regulating Panel, Reversing. (Cutler-Hammer Co.)—Wiring Diagram, Fig. 98, and Elementary Wiring Diagram, Fig. 99.

The panel is similar to the one shown in Fig. 95 with the addition of the reversing arrangement, the brake circuit and the push-button connections.

REVERSING.—The reversing switch is operated by a separate handle from the outside of the panel. The switch is so interlocked with the starting arm that it is impossible to operate the switch unless the starting arm is in the "off" position. It is also impossible to operate the starting arm unless the reversing switch is thrown entirely over to one or the other of the running positions. This prevents any arcing on the reversing switch.

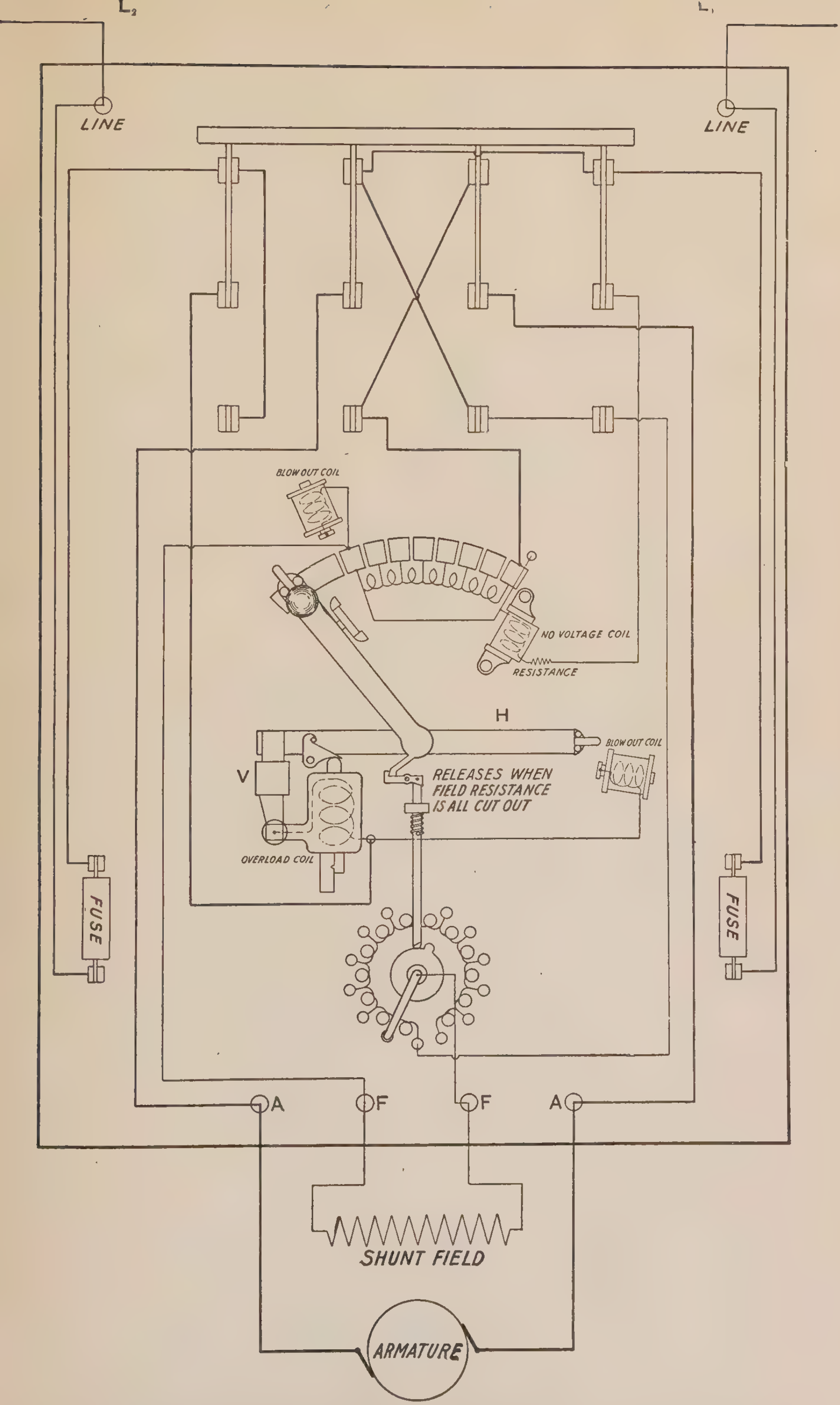

L₂
L₁
LINE
LINE
BLOW OUT COIL
NO VOLTAGE COIL
RESISTANCE
H
BLOW OUT COIL
V
RELEASES WHEN FIELD RESISTANCE IS ALL CUT OUT
OVERLOAD COIL
FUSE
FUSE
A
F
F
A
SHUNT FIELD
ARMATURE

FIG. 97.—Starting, Regulating and Reversing Panel. Watertight. Chain Ammunition Hoist. Ward-Leonard Co.

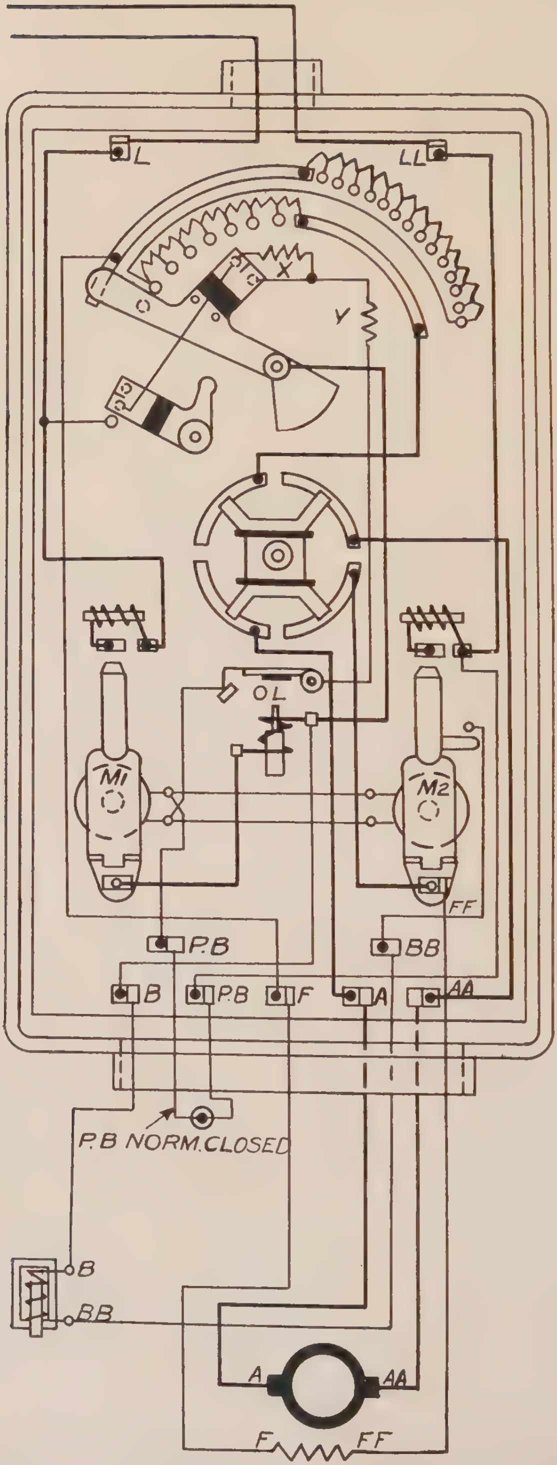

L
LL
X
Y
OL
M1
M2
FF
P.B
BB
B
P.B
F
A
AA
P.B NORM. CLOSED
B
BB
A
AA
F
FF

FIG. 98.—Regulating and Reversing Panel. Watertight. Chain Ammunition Hoist. Cutler-Hammer Co.

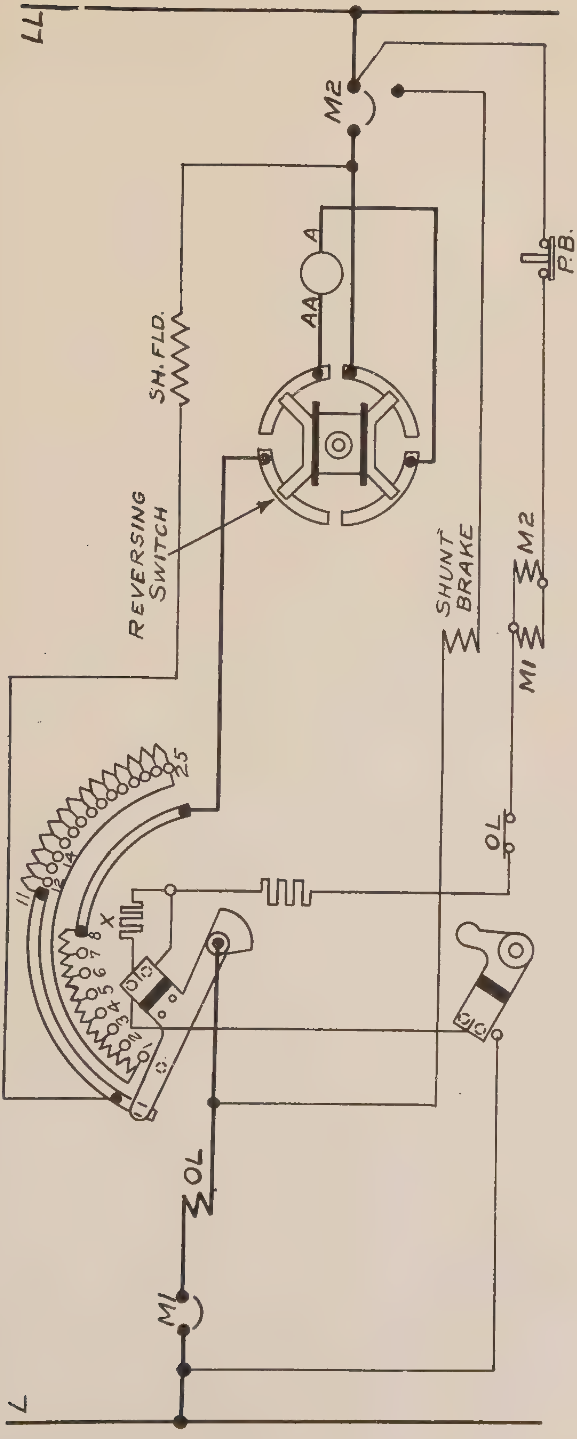

LL
L
M2
A
AA
SH. FLD.
REVERSING SWITCH
SHUNT BRAKE
P.B.
M2
M1
OL
X
1
2
3
4
5
6
7
8
11
12
14
25
OL
M1

FIG. 99.—Elementary Wiring Diagram. Chain Ammunition Hoist. Cutler-Hammer Co.

The reversing is effected by changing the direction of the current through the armature, leaving the field unchanged.

BRAKE.—The brake coil is shunted across the line, and is energized by an auxiliary contact on the main-line clapper switch M2. The brake circuit leads from this contact to terminal BB, through the brake, to terminal B, to main-line connection on the panel side of the clapper switch M1. The brake is released when this circuit is energized, and engages when it is broken. Because the connections are on the panel side of the switches, it is impossible for the motor to hold the brake released through generator action, should the load overhaul the motor after the main-line switch has been opened.

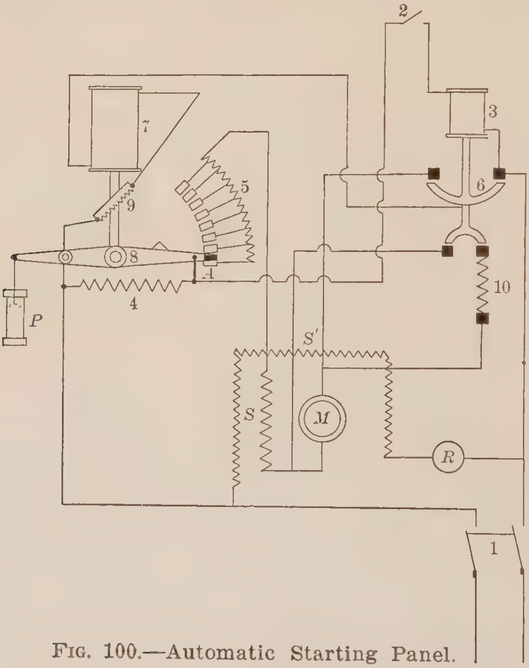


FIG. 100.—Automatic Starting Panel.

PUSH BUTTONS.—A push button is included in the shunt circuit that energizes the two clapper switches. If the button is pressed it opens this circuit, and the clapper switch is opened, stopping the motor. The push button provides a means of stopping the motor from a station remote from the panel, as at the discharge point of the ammunition hoist. It is especially useful in an emergency.

Automatic Starting Panel (Fig. 100).—This is a special type of panel so arranged that the motor will be started in the usual way, cutting resistance out of the armature circuit gradually, but the only manual operation required is the closing of a switch, at a distance from the panel. It finds application in wireless telegraphy, where the operator should be able to start his motor generator without leaving his station at the receiver.

CONNECTIONS:

This form of control is illustrated in Fig. 100. M is the motor armature, S the series field, and S′ the shunt field with its rheostat R.

When switch 1 is closed, circuit to the power mains is established through the shunt field. The single-pole switch, 2, may be removed some distance from the rest of the control circuit. When 2 is closed, the circuit is completed through the solenoid magnet 3, and over sliding contact A to starting arm and on to other side of line. Resistance 4 is cut in circuit to magnet 3 when starting arm moves, as only a small current is required to keep plunger up when home in solenoid. When 3 is energized, its plunger is pulled up and the circuit breaker 6 then completes the circuit through the armature M, series field S, resistance 5, and starting arm 8. At the same time that the armature circuit is established, current is established in the solenoid magnet 7, over short-circuiting bridge around 9, drawing up the starting arm 8, which gradually cuts out resistance 5, allowing the motor to attain its full speed. When starting arm is up, it opens short-circuiting bridge, cutting in resistance 9 in solenoid magnet 7, sufficient current still flowing to hold starting arm 8 up. The plunger of the solenoid 7 works against a dash-pot P, which prevents starting arm from operating too rapidly.

DRUM-TYPE CONTROLLER.

In general drum-type controllers are used for the control of heavy currents in motors of above 12 horsepower, but they are used in connection with motors of all sizes where frequent starting, stopping and changing of speed are required.

They are extensively used in such equipment as turret turning, gun elevating, rammers, ammunition hoists, boat cranes, and deck winches.

A drum-type controller (Fig. 101) consists of a cylinder rotated by a handle, mounted in a frame. The cylinder carries a number of "contact rings" or "contact segments," or both, that extend around all or part of its circumference.

Secured on the frame and stationary are a number of "contact fingers." The contact rings rotate with the cylinder. They are arranged, and connected to, or insulated from each other, to make the required combinations. The contact fingers have secured to them, terminals, to which are attached the wires leading to the various circuits. As the cylinder is rotated the contact fingers bear against the rings making and breaking connections.

The resistances are frequently mounted under the base of the controller, but may be separately mounted.

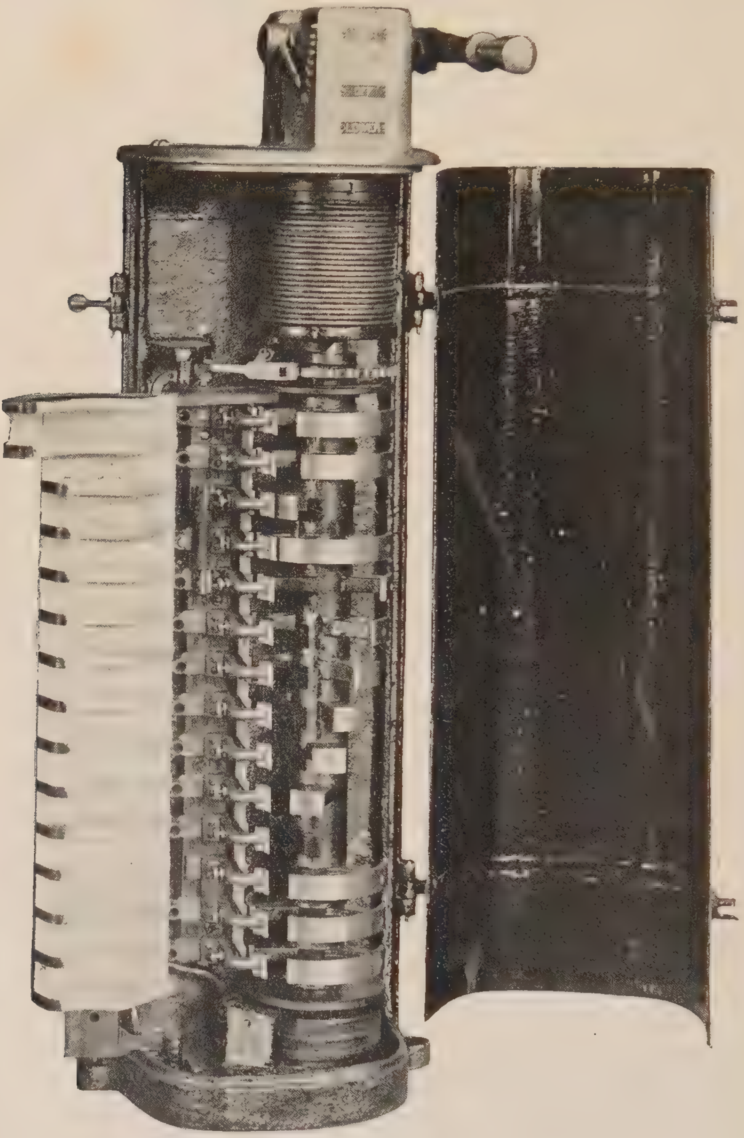


FIG. 101.—B28 E Controller. General Electric Co.

REQUIREMENTS.—The requirements for the drum-type controlling appliances are the same as for the panel-type (page 88), with these modifications:

1. (See 1, p. 88.) The starting lever must be so arranged that if it is left on any starting position, and the hand of the operator removed the circuit will be interrupted and the motor will stop; *or* the starting resistance may be furnished of such capacity that it will carry continuously for 15 minutes the rated current of the motor without being seriously damaged, in which case the above-mentioned safety device may be omitted.

2. (See 8, p. 89.) The overload device must protect the motor and controller under any possible conditions of overload.

If the overload device is of the type interconnected with and operated by the starting lever, it must be so arranged that it cannot be closed unless the starting resistance is all in the circuit.

SELF-CONTAINED DRUM CONTROLLERS.—Drum controllers of the "self-contained" type have the line switch, resistances and safety devices, the entire "controlling appliance," all mounted within the controller casing and controlled by external operating levers.

DRUM CONTROLLERS WITH PANELS.—When not of the "self-contained" type, drum controllers are furnished with a panel and the necessary resistances arranged for mounting separately from the drum. These panels are enclosed in the same manner as panel-type controllers.

A typical drum controller is shown in Fig. 101. It consists essentially of the following parts:

The *frame with cover; cylinder* or *cylinders; contact fingers; blow-out magnet; arc deflector; star-wheel, cap-plate* and *handle.*

FRAME.—The frame is of cast iron provided with a hinged front cover, in most cases made of sheet iron, but in some cases made of brass.

CYLINDER.—The cylinder is supported in bearings in the frame, and is operated by means of a handle. The cylinder is a composite structure consisting of a steel shaft upon which is mounted a hollow tube of insulating material, to which are secured brass castings carrying copper contact segments. If the tube of insulating material is made of wood the castings are screwed on; if it is made of insulating composition the castings are provided with cylindrical hubs which entirely surround the composition tube, for the reason that the insulating compositions generally used for this purpose have not sufficient mechanical strength to support castings without complete hubs. The insulating composition is put in place while plastic under the application of heat; the shaft and castings must be supported in their proper relative positions until the composition has hardened. In most cases, all those contacts which are to be electrically connected, are made in one casting, there being, consequently, a smaller number of castings on the cylinder than there are contacts. The projections on the castings, after being turned to a true cylindrical surface, are supplied with copper contact rings generally about 1 inch in width and $\frac{1}{4}$ inch in thickness, which have been shaped to a true cylindrical form, and are fastened to the projections by means of two or more screws. These contact rings are thus made removable, so that in case of burning or of injury to them, they may be replaced by new ones.

CONTACT FINGERS.—On a wooden block supported by the frame are several contact fingers, insulated by the block from each other, and from the frame. These fingers are stamped from copper, and are held in position by springs and adjusting screws, so that when the cylinder is rotated its contact rings will make firm contact with the fingers, the springs of which give sufficient pressure to insure a good electrical connection. The contact fingers are supplied with binding posts in which wires or cables are fastened, making the necessary connections between the line switch, motor, rheostat, and solenoid brake if used. In some cases these wires are carried directly out through the back of the frame, being insulated from it by rubber bushings, and in other cases the leads are carried down inside of the frame and brought out through a hole in the bottom. The fingers are fastened to their bases by means of small screws which readily permit of replacing any which may be injured. The adjusting screw is provided with a check nut, so that the screw will not jar loose, after the finger has once been adjusted. The finger bases are fastened to the wooden block by means of screws and the wooden block is fastened to the controller frame in a similar way.

BLOW-OUT MAGNET.—In order to reduce the burning of the contacts which would naturally result to some extent from the operation of the controller, a magnetic field is provided which has the effect of instantly breaking the electric arc formed when any circuit is broken. This flux is produced by means of a spool or coil surrounding the lower end of the cylinder shaft. In addition a steel pole piece is supported over the fingers, being connected magnetically at the bottom of the shaft, so that a magnetic circuit is formed, consisting of the shaft, bottom of controller frame, and pole piece, the circuit being completed by the air space between the pole piece and the shaft, forming a magnetic field across the ends of the fingers. There is, of course, some magnetic field on the other side of the controller cylinder, between it and the back of the controller, but only that portion formed between the pole piece and the shaft is used in blowing out the arc.

In some controllers, the magnetic blow-out spool does not surround the cylinder shaft, but has a separate core cast to the back of the controller, to which is attached a pole piece covering the contact fingers. In this case the magnetic field is produced between the pole piece and the back of the controller, the cylinder being in this field, and concentrating the magnetism on a line between the pole piece and the shaft, which line is near the ends of the contact fingers.

In other controllers, the magnetic blow-out spool is a long, narrow coil surrounding the tip of the pole piece and carried just over the line of the fingers. This serves to concentrate the magnetism along the line of the finger ends where the arcing takes place. In all cases the winding of the blow-out coil is in series with the armature of the motor, so that whatever current passes through the armature also passes through the blow-out coil, and produces the necessary magnetism, which is therefore approximately proportional to the current used.

ARC DEFLECTOR.—In order more thoroughly to insulate the fingers from each other and from the cylinder and pole piece, strips of fire-proof insulating material are provided extending between the fingers and pole piece, with division plates extending from this plate between the fingers themselves, and in some cases an additional plate is provided between the finger bases and the cylinder. These insulating pieces prevent the arc, when formed, from being blown from one finger to the next, thus making a short circuit, which might otherwise occur and thus impair the effectiveness of the controller.

STAR-WHEEL.—In order that the operator may judge of the position of the cylinder while operating it, without looking at it, a wheel is fastened to the cylinder shaft containing several notches or teeth, which engage a roller, supported on the end of the pawl which is pressed against the star-wheel by means of a spring. As the cylinder is rotated this pawl offers some resistance to the movement of the handle, and as it moves into the notches the effect is plainly felt by the operator, who should leave the controller handle only in the position shown by this pawl and star-wheel, because it is at these points that the fingers make the best contact with the cylinder. It should not be left at intermediate points. Also the star-wheel gives the additional advantage of making a quick break at the time of passing from one position to another, as the tension of the spring helps to turn the cylinder after the roller has passed the point between the two notches.

CAP-PLATE.—At the top of the controller is a cap-plate containing stops to limit the motion of the handle and points to show the position of the cylinder. In some instances this cap-plate is made of brass, in order not to interfere with the magnetic circuit and in other cases merely to form a more finished appearance. On some controllers the cap-plate is provided with a notch into which a latch on the handle will fall when the cylinder is turned to the off position, so that the operator when quickly stopping a motor will not carry the handle past the off position and reverse the motor.

HANDLE.—The handle consists of a brass lever having a hole in its hub, made to fit the end of the shaft and allowing it to be easily removed, and carrying at its outer end a wooden revolving piece making it more convenient to operate. On some controllers a thumb-latch is attached to the lever, which is controlled by a pin passing through the center of the wooden piece, allowing the latch to be released by pressing on the pin. The latch is pressed down by a spring so as to engage the notch on the cap-plate when turned to the off position.

This particular type shows the cylinder to be operated by the meshing of gear wheels, the smaller of which is turned by an operating wheel on top of the controller.

Developed Controllers.—In order more clearly to understand the diagrams of connections to be given under the application of motors, a so-called developed controller is shown in Fig. 102.

This shows the development of the circular contact rings on a plane surface, with the indication of the contact fingers and method of connecting the resistances.

All black lines and surfaces are conductors, the contact rings being indicated by the broad heavy lines and the contact fingers by circles. Where small white circles are shown on a black background, they indicate contact fingers resting on the contact rings.

It must be remembered that all contact fingers are stationary while the contacts are moved by the motion of the cylinder. In the diagram below a clockwise motion of the handle would result in *all* the contact rings to the right of the row of fingers moving to the left as there viewed, and all the others on the other side moving to the left. A contrary motion of the cylinder would produce opposite motion of the contact rings.

Contact is made between finger and ring when the ring is moved so that the finger rests and presses firmly on it. Connectors connecting together contact rings move with them.

Classes of Drum Controllers.—There are three general classes of controllers designed according to the kind of work they are to perform. Those made by the General Electric Company, which find almost universal use on shipboard are arbitrarily designated as R, B, and P types.

R CONTROLLERS.—The R controllers are **rheostatic** in their method of operation, and are used for the purpose of starting, stopping, reversing and controlling the speed of motors. They are particularly adapted for motors designed to carry a load in either direction. In this type of controller the combinations are such that when the cylinder is turned to the first position in one direction, the circuit contact rings on the cylinder make connection with corresponding contact fingers, connecting the motor armature and field to the line, but having in its circuit the resistance connected to the controller. On further rotation of the cylinder, the resistance is gradually short circuited, until at the last position of the cylinder the resistance is entirely out of circuit, the motor then attaining its maximum speed. On returning the handle to its original position, the resistance is again introduced into the circuit, and the motor is slowed down and stopped. When the cylinder is turned in the opposite direction, the same effect is produced with the rheostat, but the direction of current through the armature, but not through the field, is reversed.

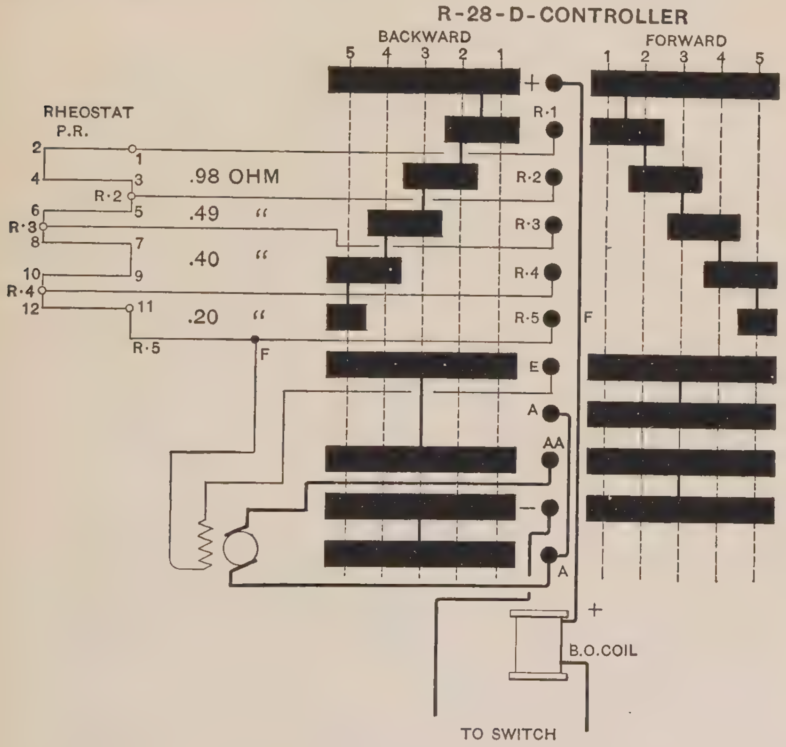

R-28-D-CONTROLLER
BACKWARD
5 4 3 2 1
FORWARD
1 2 3 4 5
+
RHEOSTAT
P.R.
R·1
2
1
4
3
.98 OHM
R·2
R·2
6
5
.49 "
R·3
R·3
8
7
.40 "
10
9
R·4
R·4
12
11
.20 "
R·5
R·5
F
F
E
A
AA
—
A
+
B.O.COIL
TO SWITCH

FIG. 102.—R28 Controller. (Developed.) Gen. Elec. Co.

A developed form of a typical R controller is shown in Fig. 102 used on turret gun rammers and formerly used for gun elevating. The motor is a series motor, the lower two lines on the left are the armature leads and the upper two are the series field leads. It will be seen how the controller connects them in series.

B CONTROLLERS.—The B controllers are those which are designed to give **electrical braking**. By this the electrical solenoid brake used in some cases is not meant, as that is simply a mechanical brake electrically operated. But in the B controller the motor is made to run as a generator by the momentum of its armature or load, and in this way reduces its speed or stops itself. There are two kinds of B controllers; in one kind the various combinations are made on a single cylinder, while in the other kind, the braking effect is obtained by means of a second cylinder independently operated. In both kinds of these controllers the contacts are arranged so that in hoisting a load the operation is exactly the same as on one side of the R controllers, but on acting as a brake controller for lowering a load, or for carrying a very light load, a different combination is made, so that the resistance to which the controller is connected, instead of being in series with the armature and gradually short circuited as the armature is brought up to speed, is connected across the line in shunt with the armature.

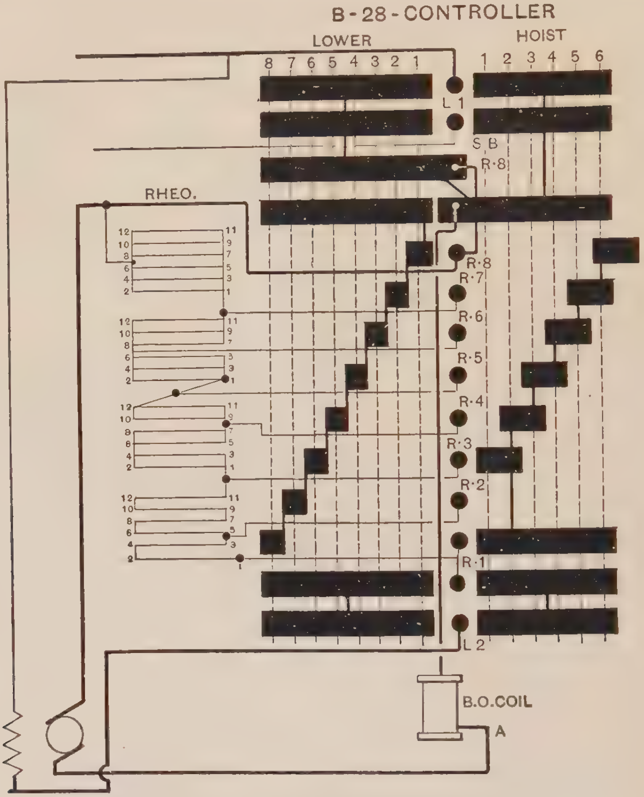


FIG. 103.—Developed Controller.

This controller is built to put in operation the Day system of control as further described under "Motor Control" in Volume I.

A developed form is shown in Fig. 103.

P CONTROLLERS.—This type of controller is used where the **voltage of the generator is to be varied in order to obtain a change of speed of the motor.** It is radically different from other controllers both in design and in system of control, although it retains the general features of all controllers, but the proportion and arrangement of its contacts are quite different. In its method of operation it introduces resistance into the field circuit of the generator in order to vary the voltage at the motor armature. The fields of both generator and motor are separately excited, and the brushes of the generator directly connected to the brushes of the motor through the reversing contacts on the controller cylinder. Under these conditions a variation in the field excitation of the generator produces immediate change in the voltage impressed on the motor armature and a consequent change in the speed of the motor.

The motor is reversed by turning the controller handle in the opposite direction from the off position, the contacts on the controller cylinder being so arranged that resistance in the generator field circuit is varied the same as before, but the direction of the current through the armature is reversed, thus reversing the direction of rotation. At the off position the armature is short circuited through a resistance, causing it to act as a generator and generate current and thus absorb energy. This produces a powerful braking effect and brings the armature to a quick stop. The suddenness of the stop may be regulated by adjusting the resistance thus introduced into the armature circuit.

The P type of controller is used for turret control, both under the original Ward-Leonard system, in which the field of the main ship's generator is controlled, and in the later motor generator system, in which the generator field of the motor generator is controlled, and still later in the rotary compensator system in which the fields of two machines are controlled. All these systems will be described later.

The electrical connections of a controller of this type will be described under "Motor Applications."

CONTACTOR-TYPE CONTROLLER.

In this type of controller the main motor circuits are made and broken by electrically operated switches, contactors and relays. These are mounted on a "contactor panel." The operating circuits for them are controlled by a master switch, or controller, that may be located at any desired distance from the contactor panel.

By this means the circuits that lead to the master switch, or controller, carry only the small currents necessary for operating the main switches, contactors, etc. Also there may be several master controllers at different places.

Contactor Panel (Fig. 104).—This panel is of the usual insulating material, and carries in addition to the switches, etc., the protective devices and terminals. It is enclosed in a frame that is flame proof, watertight, or non-watertight, as may be required in each instance.

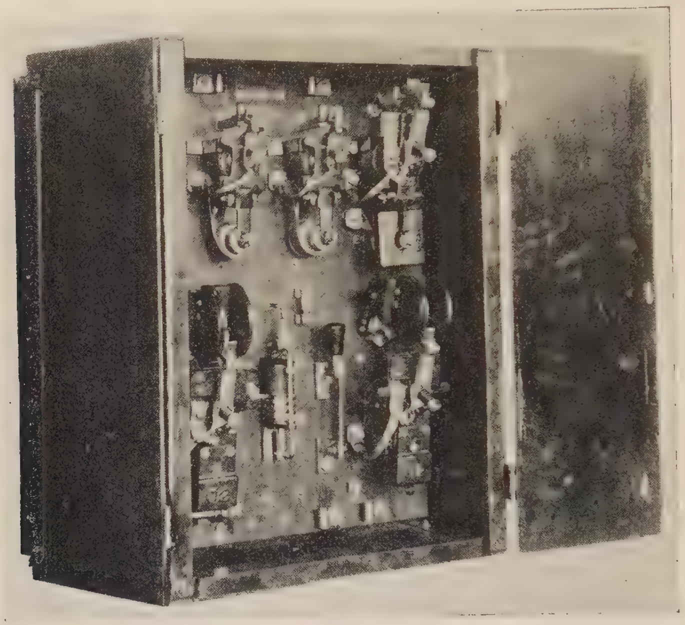


FIG. 104.—Contactor Panel.

Master Controller.—The master controller may be a drum-type controller, a knife switch, or merely a push-button switch.

CHAPTER VI.

APPLICATIONS OF MOTORS.

Motors are now used on modern ships for such a great variety of purposes, and so many different arrangements are used for their control in order to meet the requirements of the service, that no attempt can be made to describe them all. Typical examples covering the important applications of motors will be described and illustrated with an explanation of how the requirements in each case have been met, and of the principles involved.

The generating sets for ship service are all direct-current machines, and nearly all the motors in the service use direct current. Alternating-current motors driven by motor generators are, however, used in a few cases for special service, and alternating-current motors are used on the latest battleships for driving the propellers. In this chapter only direct-current motors will be considered.

GALLEY APPLIANCES.

Motors are now used to operate a number of galley appliances, some of which are:

Meat and food grinders.
Ice cream freezers.
Kitchen and cake machines.
Dough-mixing machines.
Dish-washing machines.
Potato peelers.

REQUIREMENTS:

Small starting torque.

A limited number of speed changes or, in most cases, constant speed. The load is light and uniform, except in the case of the meat chopper, which is subject to sudden increase of load.

MOTORS.—The motors are shunt wound (except for meat chopper, the motor of which is compound wound), open or enclosed, depending on protection required, from ½ to 2 horsepower.

CONTROLLING APPLIANCES.—Panel-type controllers for starting only, or simple panel type for starting and regulating when required, are used.

LAUNDRY MACHINERY.

In the first sets of electrically equipped laundry machinery, one motor was used to drive a line shaft, and the various machines were driven by belts from this shaft. The motor on the *New York* is a shunt wound, Type K Diehl motor with interpoles, controlled by an enclosed panel controller for starting duty only. An additional motor is used for the conveyor. This is a ½-horsepower, shunt-wound, open motor with panel controller for starting only. In specifications for later ships, the various machines are driven directly by separate motors.

MOTORS.—The motors are from ⅛ to 2 horsepower, semi-enclosed, shunt or compound.

CONTROL.—The control consists of fused line switch for the smallest motors. Panel type starting, or in some cases starting and regulating, controllers are used with larger ones. Motors for the washer and extractor may be supplied with contactor type controllers.

Extractor Controller.—The wiring diagram of the controller for the extractor, as installed on the *Nevada,* is shown on Fig. 105 and elementary diagram Fig. 106. It is a contactor type controller, non-reversing, for starting duty only. The panel is enclosed in a sheet-iron case with hinged doors. There are mounted on the panel a double-pole clapper-type switch, M, a single-pole clapper-type switch, RI, a series relay, SR, resistance 1-2, and overload device, OL. When the solenoids of the switches are energized, connection is made with the contacts shown immediately above them. A double push button placed near the machine is used to operate the controller.

OPERATION.—The "off" button is held *closed* by a spring. It can be opened by pressing on it, but will close if the pressure is removed. The "on" button is held *open.* It can be closed by pressing on it, but will open if the pressure is removed. If the "on" button is depressed, the operating circuit through the switch M is closed, completing the shunt-field circuit, and completing the armature circuit through resistance 1-2 and series relay SR. This gives the motor about 225 per cent normal inrush of current, which starts the motor accelerating rapidly. As the motor increases in speed, the current decreases and, when somewhat below normal, the series relay armature SR lifts, by action of the spring. This completes the operating circuit for the single-pole clapper switch and it closes, cutting out the resistance, 1-2, and throwing the motor across the line.

If the "on" button is released at any time after the contactor M closes, the operating circuit for M is made through the resistance x and an auxiliary contact on M. Enough current flows to keep M closed, but not to close it if it is open.

If the "off" button is depressed, the operating circuit for M is broken, M opens and the motor will stop. If the voltage fails, M opens. In case of *overload,* the series coil of the overload magnet will draw up the plunger, opening the switch over it, opening the operating circuit of M.

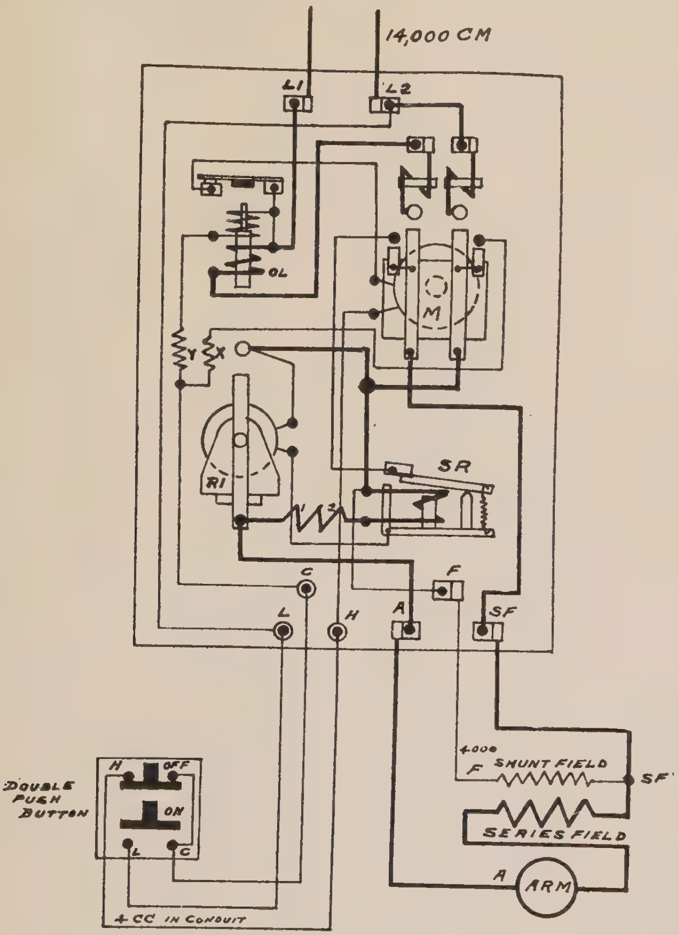

14,000 CM
L1
L2
OL
M
Y
X
RI
SR
1
3
C
F
L
H
A
SF
F
SHUNT FIELD
SF
SERIES FIELD
A
ARM
DOUBLE PUSH BUTTON
H
OFF
ON
L
C
4 CC IN CONDUIT

FIG. 105.—Wiring Diagram, Controller for Laundry Extractor.

The shunt coil has little effect on the small part of the plunger in the position in the figure; but, if the plunger is raised so that the part of the large diameter is inside the shunt coil, that coil will hold it up, as long as the coil is energized. That is until the contactor M is open and the current in the shunt coil fails.

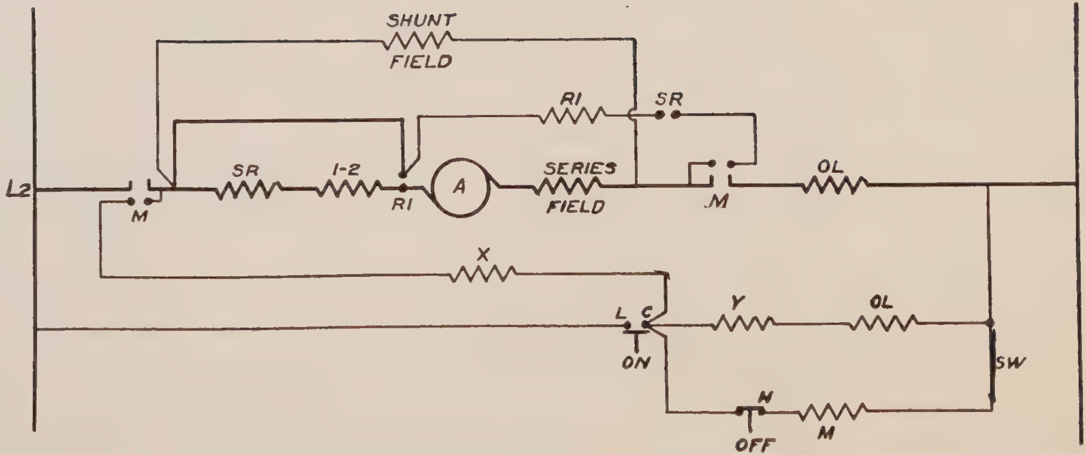

SHUNT
FIELD
R1
SR
L2
M
SR
1-2
R1
A
SERIES
FIELD
M
OL
L1
X
L
C
ON
Y
OL
SW
N
OFF
M

FIG. 106.—Elementary Wiring Diagram, Controller for Laundry Extractor.

VENTILATING BLOWERS.

Desk and Bracket Fans.—These small motors of $\frac{1}{6}$ and $\frac{1}{12}$ horsepower are **series wound** and fitted with three speed contacts, effected by varying the resistance in series with the armature and field.

The connections of the controlling and starting switch with the rheostat are shown in Fig. 107.

The connection board B is of porcelain, mounted in the base of the bracket or stand. A is the starting arm, moving over the contact pieces shown, which are connected to different portions of the rheostat, or starting resistance R. On the first contact, as shown, the circuit is open, and on moving A to the right on the first contact, the circuit is established from the supply main to the motor field, then through the armature, back to the pivot contact of A, then through all of the resistance R, back to the other main. On the second contact, more resistance is cut out, and on the last contact R is short circuited when the motor is running at full speed.

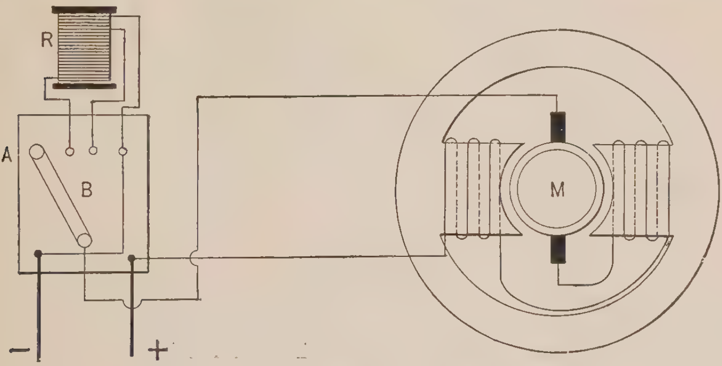


FIG. 107.—Connections of Desk Fans.

Fixed Ventilating Fans.—These fans are operated by direct-connected motors. They vary in power from .88 horsepower, for small fans delivering 1000 cubic feet of air per minute, to 14 horsepower, for large fans delivering 20,000 cubic feet per minute.

REQUIREMENTS.—The requirements for such fan motors operating under practically uniform load are:

Small starting torque.
Constant speed, or a limited number of speed changes.
Continuous running, infrequent starting and stopping.

MOTORS.—The motors are all shunt or compound wound, usually with interpoles, open or enclosed, depending on the protection required.

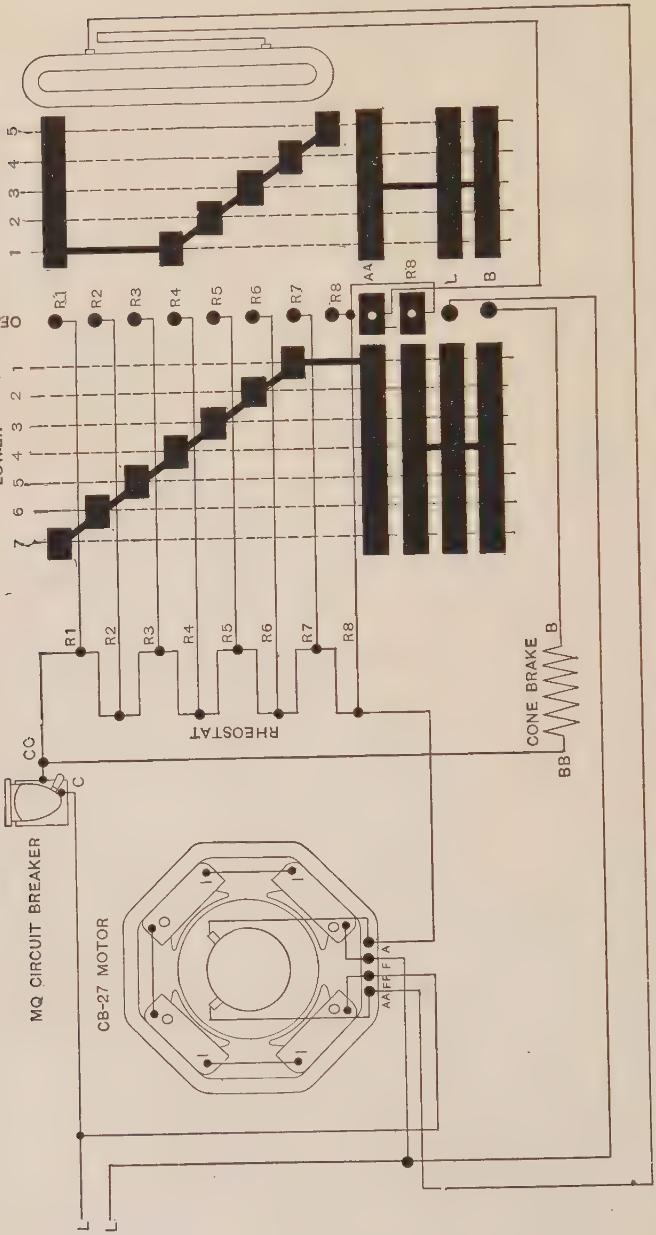

B-34-B CONTROLLER
LOWER
HOIST
OFF
1
2
3
4
5
6
7
R1
R2
R3
R4
R5
R6
R7
R8
AA
R8
L
B
RHEOSTAT
CONE BRAKE
B
BB
CC
C
MQ CIRCUIT BREAKER
CB-27 MOTOR
A
F
FF
AA
L
L

FIG. 108.—Whip Hoists. Wiring Diagram. Gen. Elec. Co.

CONTROLLING APPLIANCES.—These are panel-type controllers, starting and regulating. Speed regulation is by field control. Panels illustrated by Figs. 92 and 93, with others of similar design, are used.

CHAIN AMMUNITION HOISTS.

Each hoist consists of a pair of endless chains, traveling over sprocket wheels at the point of loading and at the point of delivery. These chains support between them carriages placed at proper intervals for receiving the ammunition, the whole being driven by an electric motor through a system of gearing.

REQUIREMENTS:

Small starting torque.
Reversibility.
A limited number of speed changes.
Provision for frequent starting and stopping.
Brake, to prevent running backward if current fails; to hold at any point.

MOTORS.—Shunt wound, interpole, reversible, equipped with electric brake that releases when current is on, and sets when current fails.

CONTROLLING APPLIANCE.—Panel type, watertight, reversing, of the types described on pages 101 to 108.

WHIP HOISTS.

These are generally installed for hoisting ammunition for the secondary battery between decks or bridges, by means of rope whips.

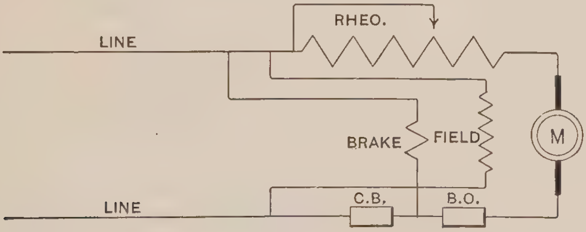


FIG. 109.—Elementary Diagram—Whip Hoist.

Electrical Equipment.—Each equipment consists of an enclosed **waterproof shunt motor,** having its armature shaft geared to a drum shaft and operated by a **drum controller** and **rheostat.** The diagram of connections is shown in Fig. 108 and the elementary diagram in Fig. 109.

The armature shaft of the motor is fitted with a magnetic cone brake, so constructed that the friction is released as soon as the controller is turned to the hoisting or lowering position, but promptly operates as soon as the controller is turned to the "off" position, or current fails through any cause.

The controller is of the B type, and in lowering produces the braking effect of the Day system of control. The armature is also short circuited on the "off" position of the controller.

PUMPS.

In late types of battleships, the following pumps are electrically operated:

Main drainage, secondary drainage, fresh water, sanitary, circulating, ballast and bilge pumps.*

All of these pumps discharge normally against small head. The load varies from no load, in case of loss of suction, to full load, if the pump is working properly and has full suction. Variation in discharge head similarly affects the load, and the load is increased in case of partially closed discharge valve in a reciprocating pump.

REQUIREMENTS:

Small starting torque.
A limited number of speed changes.
Provision for frequent starting and stopping.
To operate satisfactorily under varying load.
Not to race in case of losing load as when the pump loses its suction.

The power required is from 3 horsepower for small pumps to 65 horsepower for main drainage pumps.

MOTORS.—The motors are compound wound, interpole and open, semi-enclosed or enclosed, depending on protection required.

CONTROLLING APPLIANCES.—The controlling appliances for the small pumps are usually:

1. Panel-type controllers for starting only.
2. R drum controller, non-reversible for starting duty only.
3. Contactor type, similar to the extractor controller described, for starting only, or with speed regulation.

Main Drainage Pump.

Controlling Appliances.—The wiring diagram of the contactor type controlling appliance, consisting of master controller and contactor panel for the main drainage pump, is shown in Fig. 110.

CONTACTOR PANEL.—On the front of the panel are mounted:

Two line contactors (Nos. 1 and 2 on diagram).
Four accelerating contactors (Nos. 3, 4, 5 and 6).

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* Of these pumps the sanitary, circulating, and ballast pumps are always centrifugal; the fresh water and bilge pumps reciprocating; drainage both types.

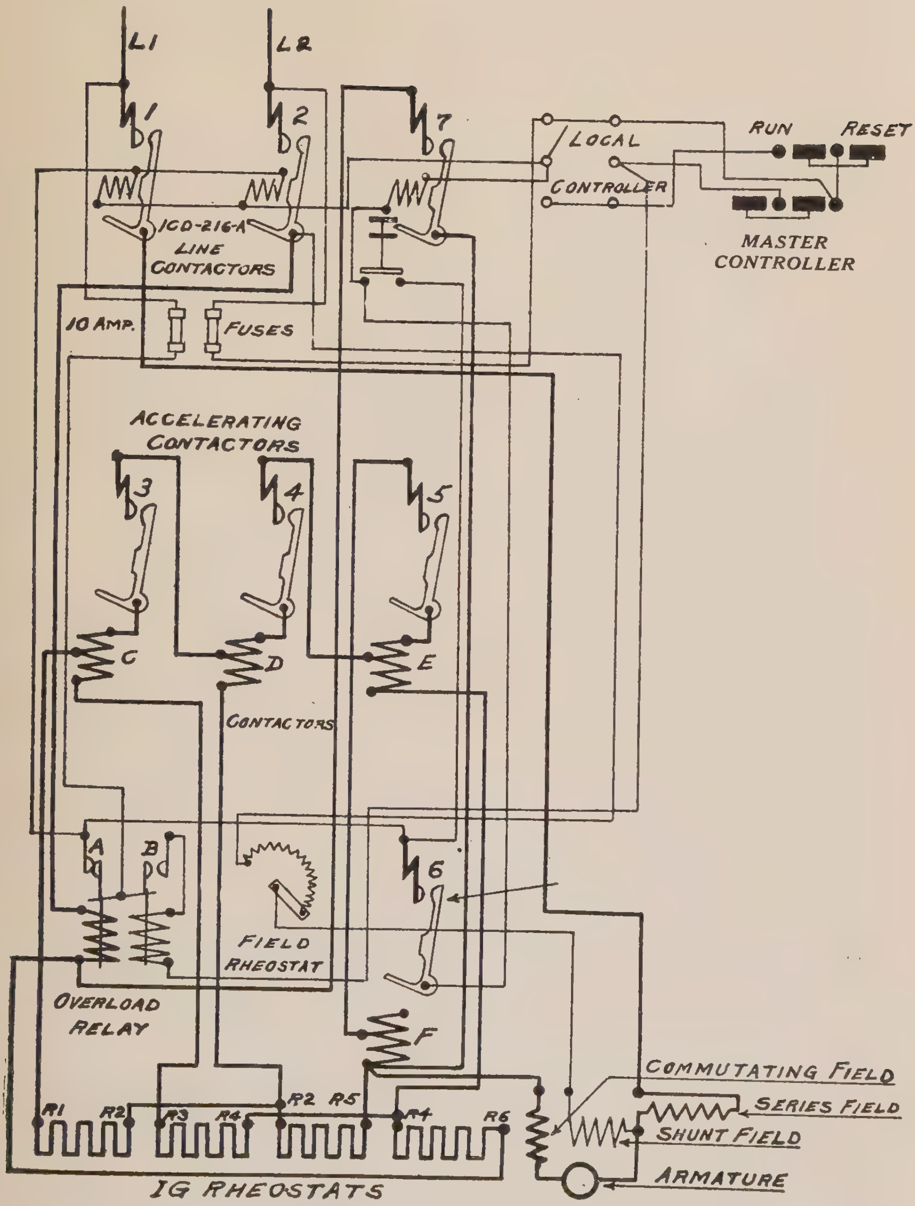

L1
L2
1
2
7
LOCAL
CONTROLLER
RUN
RESET
MASTER CONTROLLER
ICD-216-A LINE CONTACTORS
10 AMP.
FUSES
ACCELERATING CONTACTORS
3
4
5
C
D
E
CONTACTORS
A
B
6
FIELD RHEOSTAT
OVERLOAD RELAY
F
COMMUTATING FIELD
SERIES FIELD
SHUNT FIELD
ARMATURE
R1
R2
R3
R4
R2
R5
R4
R6
IG RHEOSTATS

FIG. 110.—Main Drainage Pumps. Wiring Diagram. Gen. Elec. Co.

One shunt contactor for cutting out the series contactors at the last point (No. 7).

One overload relay.

Two fuses for control circuits.

One single-pole double-throw, selective switch for local operation and disconnecting master controller.

One operating handle for field rheostat.

The *Accelerating Contactors* are of the current limit series type, without blowout. Their construction is such that, when the circuit is closed, these contactors will not close until the current is reduced to a predetermined amount for each step (described on page 77).

OPERATION.—When operating the panel by the master controller the single-pole switch must be closed downward. When the master controller is moved to the running position, the two line contactors will close, the circuit being closed through the motor with all resistance in series. When the speed of the motor has accelerated sufficiently and the current has in consequence become reduced to a predetermined amount, the magnetic effect in coil C will be reduced sufficiently to allow contactor No. 3 to close, cutting out resistance R1-R2. When the current is again sufficiently reduced in coil D, contactor No. 4 will close, cutting out resistance R3-R4. When the current is sufficiently reduced in coil E, contactor No. 5 closes, cutting out resistance R2-R5. When the current is sufficiently reduced in coil F, contactor No. 6 closes. When contactor No. 6 closes, the operating coil of contactor No. 7 is energized and this contactor closes, thereby cutting out resistance R4-R6, and the motor is running directly across the line, all resistance being cut out.

When contactor No. 7 closes, it forms its own holding circuit to the disc interlock, and the accelerating contactors will drop out, due to the fact that their coils are short circuited. When it is desired to test out the panel or the leads, the small control fuses may be removed, thereby making all parts of the apparatus dead.

By consulting the diagram of connections (Fig. 110), it will be noted that at all times the current passes through the series coil of the overload relay, the normal position being with the contacts A closed. Should there be an overload on the motor, or excessive rush of current from some other cause, the plunger of the series coil will be drawn up, causing A to open and B to close. Contacts A open the control circuit of the line contactors, which in turn causes all contactors to open. This condition will remain until the controller is brought to the "reset" position, when the shunt coil of the overload relay will be energized, drawing up its plunger which opens contacts B and closes A. When the above has taken place, the panel can again be operated and the motor started as described above. Contacts B are not open until the operating levers have returned to their normal positions so that the shunt coil is in circuit only momentarily.

The panel can be operated locally by closing the single-pole switch upward. When this is done, should an overload occur for any reason, contacts A will open and B will close as described above. The design of the panel is such that when this condition occurs, the overload relay must be reset by hand. This can be done by lifting the A plunger by means of a knob provided for that purpose.

TORPEDO AIR COMPRESSORS.

Torpedo air compressors are usually motor driven. Small starting torque is required, but the load increases as the pressure increases. A 25 per cent speed reduction from the maximum is required. Reversing is not required.

MOTORS.—The motors in late ships are compound wound, open or semi-enclosed, 52 horsepower. They are direct connected to the air compressor.

CONTROLLING APPLIANCES.—A panel type controller, arranged for starting and for field regulating, is used for the control.

DECK WINCHES.

Deck winches are used on the upper decks, forecastle and quarter deck for general deck use, hoisting boats, hoisting on board stores, ammunition, etc., and in coaling ship. They must be entirely watertight and dust tight and mechanically and electrically strong.

REQUIREMENTS:

Large starting torque, in order to start with full load.

Ability to withstand large and sudden changes of load, as when taking in slack line and suddenly getting full weight of a boat or when load is thrown off.

Frequent changes of speed, starting and stopping.

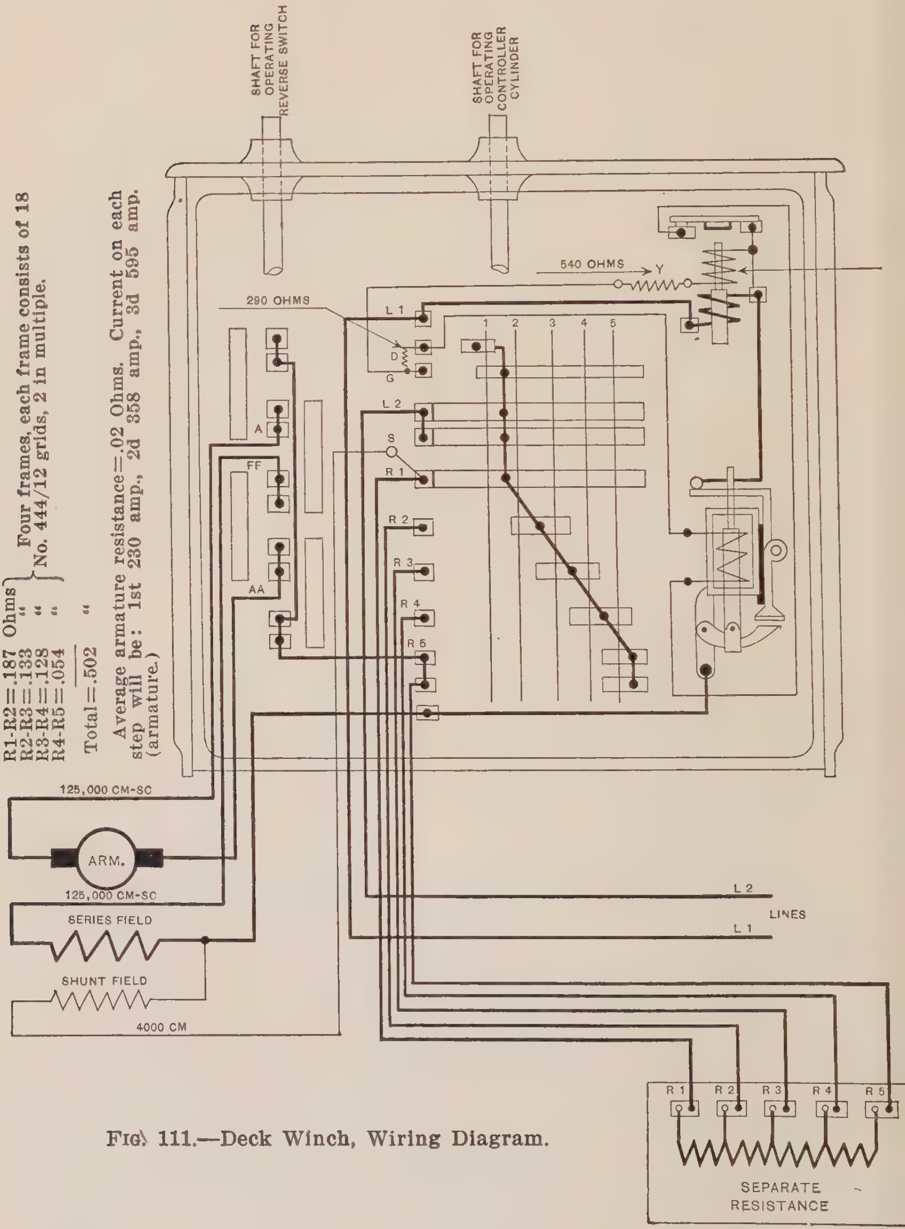
Ability to hold load if current fails.

Reversibility.

Changing from "high speed" to "low speed" is accomplished by mechanical change of gearing.

MOTORS.—The motor is cumulative compound wound, with interpoles, enclosed. It is geared to the shaft of the winch. The motor feet are hollow at the commutator end to allow for entrance of leads from the bed plate.

CONTROLLING APPLIANCES (Fig. 111).—These consist of a drum controller, watertight, reversing type. The watertight frame contains a controlling drum, a separate reversing drum, contactor, overload device, resist-


SHAFT FOR OPERATING REVERSE SWITCH
SHAFT FOR OPERATING CONTROLLER CYLINDER
540 OHMS
Y
290 OHMS
L 1
D
G
1
2
3
4
5
L 2
S
R 1
R 2
R 3
R 4
R 5
A
FF
AA
125,000 CM-SC
ARM.
125,000 CM-SC
SERIES FIELD
SHUNT FIELD
4000 CM
L 2
LINES
L 1
R 1
R 2
R 3
R 4
R 5
SEPARATE RESISTANCE

R1-R2=.187 Ohms } Four frames, each frame consists of 18
R2-R3=.133 " } No. 444/12 grids, 2 in multiple.
R3-R4=.128 "
R4-R5=.054 "

Total=.502 "

Average armature resistance=.02 Ohms. Current on each step will be: 1st 230 amp., 2d 358 amp., 3d 595 amp. (armature.)

FIG. 111.—Deck Winch, Wiring Diagram.

ance units for solenoid holding resistance. The armature resistances are mounted separately in a watertight frame secured to the winch bed, or, for better protection, mounted below the deck. All electric leads pass through a watertight passage cored in the bed plate.

Main Controller Drum.—This drum closes the shunt field and cuts resistance in or out of the armature circuit. Five changes of speed are provided for. The shunt field is not used in regulating the speed.

Reversing Controller Drum.—This drum is operated by a separate handle. When it is in the "off" position the armature circuit is broken. When moved to the right, the armature circuit is made in one direction and, when moved to the left, it is made in the opposite direction. The direction of the circuit through the series field is not changed. The drums are mechanically interlocked so that it is impossible to operate the starting handle with the reversing lever in the "off" position. Furthermore, the reversing lever can be moved only when the operating handle is in the "off" position.

The connections and uses of the contactor and overload device can be followed and understood from previous descriptions.

WATERTIGHT DOOR AND HATCH EQUIPMENT.

If electric power is used for operating doors and hatches, the following control must be obtained:

1. Each door or hatch must be capable of operation on the spot by power or by hand from either side of the bulkhead or deck, the closing by power not to require more than 20 seconds. Bunker doors will not be fitted with hand gear on the bunker side. When the doors are operated from the berth deck a device will be fitted which will automatically disconnect the above hand gear when current flows in the armature circuit and connect it again when current is cut off from the armature.

2. All doors and hatches must be capable of being closed by power from a central emergency station. All doors and hatches must be closed within two minutes from the time of operating the emergency station.

3. During any period of emergency closing full control must be maintained for opening any individual door or hatch on the spot, by power from either side of bulkhead or deck, and after any such individual opening during the emergency period the emergency closing must repeat itself automatically.

4. Approved means will be provided for indicating at the emergency station during every emergency period when each door and hatch is shut and locked.

5. The motor at each door and hatch must be so designed that it will not injuriously heat with the armature standing still and drawing full current from the line in case the door or hatch meets an impassable obstruction; or an automatic cut off must be provided which will shut off the current from the motor when the power developed has reached a predetermined amount, and will again turn on the current after the obstruction has been removed. The door in the open position, and the motor and gearing, must be completely encased to prevent fouling of the operating parts.

Power is conveyed from each motor through gearing to the door or hatch; for vertical doors, a worm engages directly with a worm rack on the door, and for horizontal doors, a worm engages a worm wheel, actuating a shaft, which carries pinions engaging with racks on the doors.

The motor with its controller is mounted in a power box, and in addition to the connections to each motor there is an auxiliary circuit leading to an emergency station or stations, in the charthouse, or on the bridge, which controls a device for showing automatically whether the door is open or shut. The emergency station is fitted with a switch by which current is sent through all the operating motors, so that the doors or hatches may be closed almost simultaneously, current being on four or five motors at a time.

The **controller** is a somewhat complicated affair and must perform the functions mentioned above, that is, it must be designed (1) to allow each door or hatch to be opened or closed by local working, (2) to allow each to be operated practically at the same time from the emergency station, (3) to allow each or any door or hatch to be operated locally when closed from the emergency station. In the last operation a door or hatch that has been closed from the emergency station may be opened locally, but it will immediately close automatically if the emergency switch is closed. When each door or hatch is completely closed or meets with an unyielding resistance, a limit switch in the controller acts to cut off the current to the motor for closing, but leaves current on for operating the door for opening.

Wiring Diagram.—The general scheme of wiring is shown in Fig. 112.

L_1 and L_2 are power mains with connections to the main switchboard or distribution boards. The motors M are compound wound, bipolar and iron-clad type, controlled each by its controller marked C. The emergency switch is marked E, and when this is turned in the direction of the arrow, circuit is completed through the right-hand positive connection from the power mains to and through the switch, through the solenoids S, and to the negative main. The energizing of the solenoid attracts the core and this closes the emergency switch in the controller, which sends current through each motor by its connection to the power mains. When each motor has closed its own door, the motor can still be controlled for opening by operating the local switch at the controller, but on releasing it, the motor will immediately operate to close the door as long as the emergency switch is closed.

As each door is closed, circuit is made by means of the auxiliary contact, A, through a lamp, 1, 2, etc., at the emergency station to the push button P. When this button is pressed the lamps for all doors closed are lighted. This shows at a glance which doors are closed and which are open. These lamps are also lighted when each door is locally closed and the button P is closed. This button is normally kept open, but to tell which doors in the ship are open or shut, it is only necessary to close the contact P.

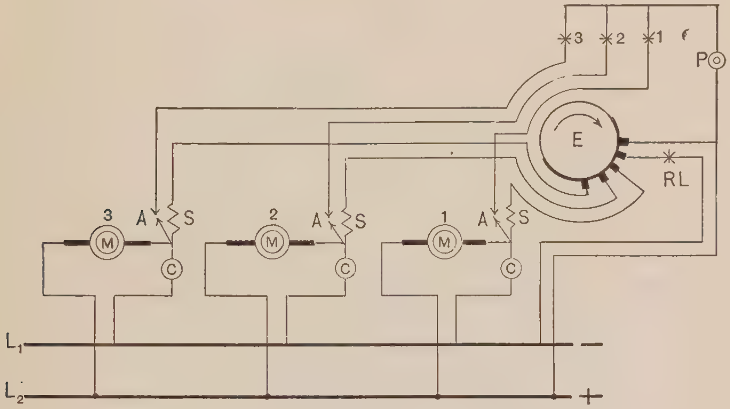


FIG. 112.—Wiring Diagram, W. T. Door Equipment.

In order to make sure that current is on, there is a tell-tale red lamp, marked RL, and so connected that as soon as current goes through the first solenoid, the lamp will glow and will continue to burn until the emergency switch is turned to the "off" position.

TURBINE TURNING EQUIPMENT.

Motors are used to permit turning over turbines for inspection and repair, also for warming up prior to starting.

MOTORS.—The motors are saturated field-shunt motors (see Chapter III for description). They are rated at 5 horsepower, but with this type of winding they can stand as much as 15 and 20 horsepower for short intervals with "black" commutation. The range from 300 to 600 R. P. M. is made by field control and as a rule heavy overloads would be imposed at the full field condition, but the motors can stand over 100 per cent overload even at the weak field.

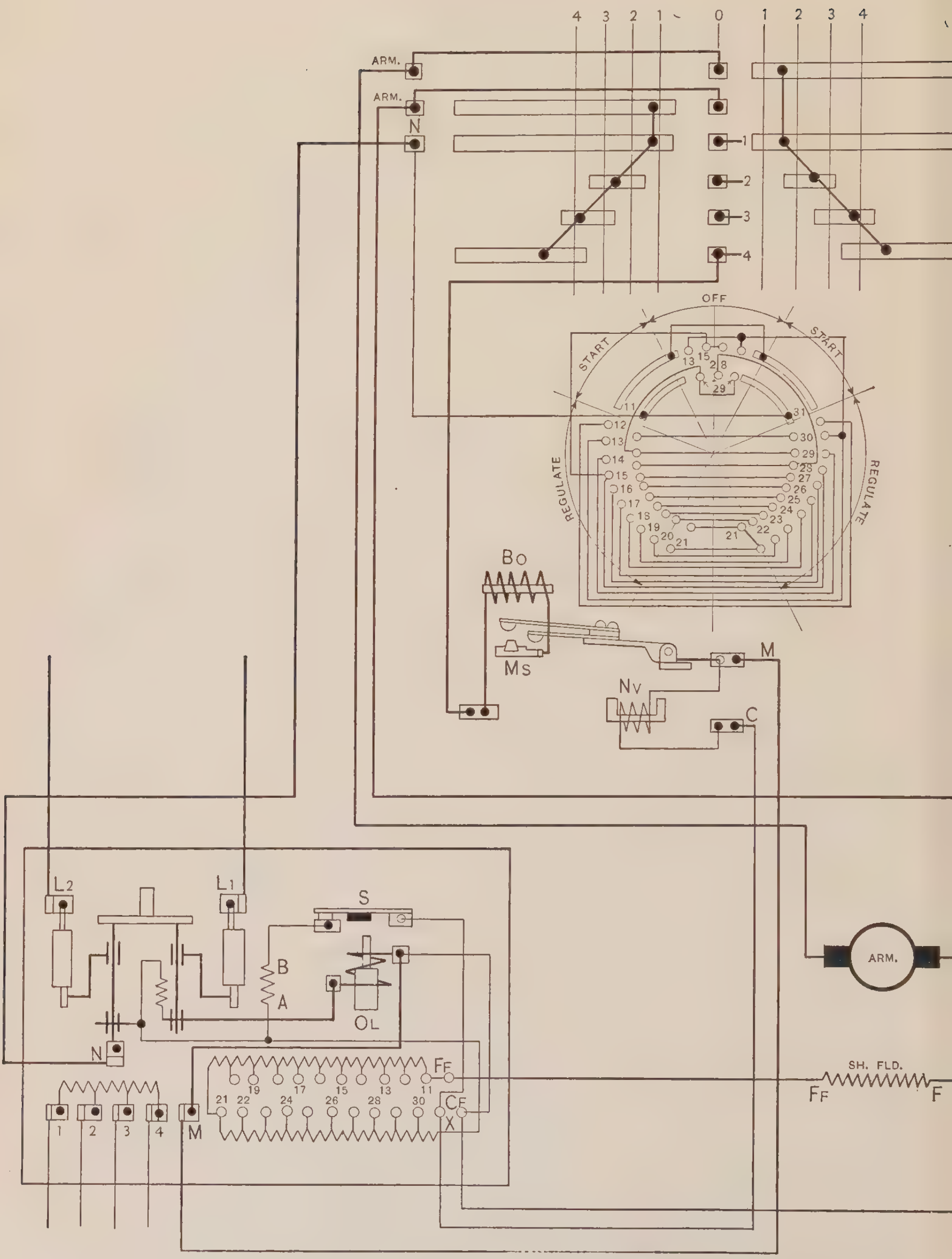

4 3 2 1 0 1 2 3 4
ARM.
ARM.
N
1
2
3
4
OFF
START
START
REGULATE
REGULATE
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
Bo
Ms
Nv
M
C
L2
L1
S
B
A
OL
N
FF
CF
X
M
1
2
3
4
ARM.
SH. FLD.
FF
F

FIG. 113.—Turbine Turning Equipment. Wiring Diagram. Cutler-Hammer Co.

CONTROLLING APPLIANCES.—The controlling appliances consist of

A drum controller.

Rheostat.

Panel, mounted on the front of the rheostat frame, containing double-pole line switch, fuses, overload relay, and terminals.

DRUM CONTROLLER.—This controller is similar in the usual details of construction to the full-reverse type of R controller, but contains additional provision for field regulation. There is mounted in its base a field resistance contact board shown in plain view on the wiring diagram. The numbered contacts are connected to the corresponding resistances in the rheostat. An arm on the lower end of the drum shaft carries brushes that are electrically connected, and move over two circles of contacts.

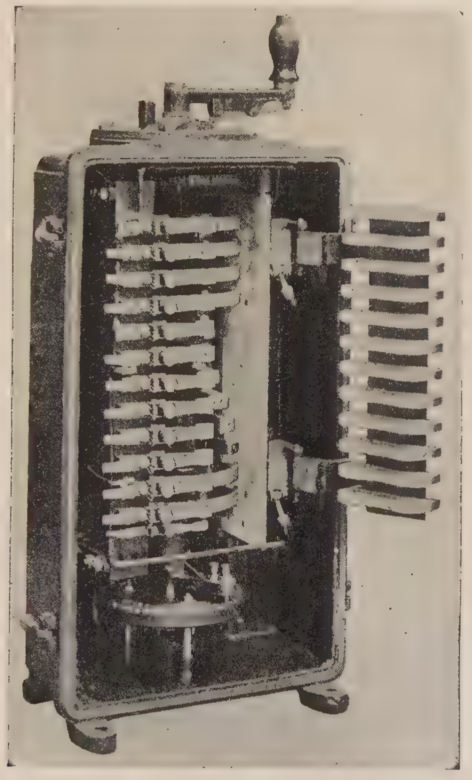


FIG. 114.—Controller, Turbine Turning Equipment.

There is also a main switch MS, closed by mechanical connection with the operating shaft of the controller. The main switch has a powerful magnetic blowout for rupturing the arc, and no-voltage release coil NV, electrically connected with the switch S of the overload relay OL on the resistance panel. Fig. 114 is a controller similar to this. The arrangement of the field resistance contact board and arm are clearly shown.

PANEL.—On the panel are mounted

A double-pole line switch.
Fuses.
Overload device.
Terminals for line and armature and field resistances.

Overload Device.—The overload device consists of a solenoid connected in series with the line and with a plunger designed to lift at a predetermined and adjustable value of the line current. The lifting of this plunger opens a small switch S at the top of the device. This switch is in series with the release coil of the main switch in the base of the drum controller. Manual resetting of this switch is unnecessary, all operations being performed by the one controller handle.

STARTING.—In starting the motor it is simply necessary to move the controller handle to either side of the "off" position, cutting the starting resistance out step by step in the usual way. When the controller is in the "off" position the main switch in the bottom of the controller case is held open by a spring, but shortly after the first drum finger makes contact on the drum cylinder a cam on the drum shaft closes the main switch if the no-voltage release coil is energized. The release coil is connected in series with the switch lever of the overload relay on the resistance panel, and accordingly if voltage fails on the line or the overload relay opens, the main switch will open. This will take place with the controller on either the starting or running points and it is then impossible to close the switch except by bringing the controller to the "off" position when the switch will close itself if the voltage has been restored to the line. The main switch is provided with a powerful magnetic blowout which efficiently ruptures the arc at all times when opening the line circuit and has easily renewable arc rupturing contacts. This switch, therefore, functions as a single-pole line switch, no-voltage release mechanism and overload circuit breaker.

FIELD CONTROL.—When the controller is in the "off" position a few sections of field resistance are left inserted in the motor-field circuit to prevent overheating of the field in the event of the motor being allowed to stand with fields energized. Thus, in Fig. 113, when the controller handle is in the "off" position, contact is made between buttons 28 and 15, to which the corresponding numbered terminals of the field resistance units are connected. The field current then flows from L_2 through the field resistance to terminal 28, to 28 on the controller, to 15 on the controller, to 15 on the resistance, through resistances 15 to 11 to and through the shunt field to the L_1 side of the line, thus leaving the resistances from X to 28 and 15 to 11 in circuit.

When the operating handle is moved one way or the other, button contacts 29 to 13 on the controller are connected, which has the effect of connecting terminals 29 to 13 in the field resistance, thus cutting out a portion of the resistance in circuit. When the handle is moved still further to the segment marked "start," the field-resistance contact board gets current from controller terminal marked N which is connected to the inner segment, which in turn is connected by the pencil contact points carried by the operating handle to the outer segment, which in turn is connected to field-resistance terminal 11. This results in short circuiting the field resistance and the field gets full-line voltage.

During the time the motor is attaining its speed by the cutting out of the armature resistance, the contact pencil points are moving over the segments in the arc marked "start." During the time that the operating handle is being moved over the field contacts, the main segments of the drum controller are moving under their fingers with all starting resistance cut out. When the contact arm reaches the point marked 12, the other pencil contact is resting on the corresponding contact on the inner row which is connected to 30 on the other side. This results in connecting terminals 30 and 12 of the resistance units, and adding a resistance to the field from X to 30 and 12 to 11. The next position connects 13 and 29, and the resistance then in the field is from X to 29 and 13 to 11. Each successive movement of the arm carrying the pencil contacts throws in circuit two units of resistance until contact 21 is reached when all the resistance is in circuit. As the inner rows of contacts on the controller as well as the outer rows are cross connected, the same resistance is thrown in the field circuit for corresponding positions of the operating handle in either direction.

This same controlling equipment is used for many motors which operate machine tools in the workshop of modern battleships.

TURRET-BLOWER EQUIPMENT.

The requirements for turret blowers are the same as for other blowers except that speed regulation over a considerable range is required to regulate the air pressure in the turret.

CONTROLLING APPLIANCES.—A drum controller, watertight, flame-proof and self-contained is used. (Wiring diagram Fig. 115.) The armature, starting and field resistances, main-line switch, overload device, and no-voltage release are all mounted in the controller case.

The main operating handle on the outside of the controller controls the starter and speed regulator as well as the main-line switch.

At the top of the controller is also a small auxiliary lever operating an auxiliary switch L within the controller case and by means of this auxiliary lever and switch it is impossible to leave the operating lever on any of the starting points, but after the main lever has been moved to any of the run-

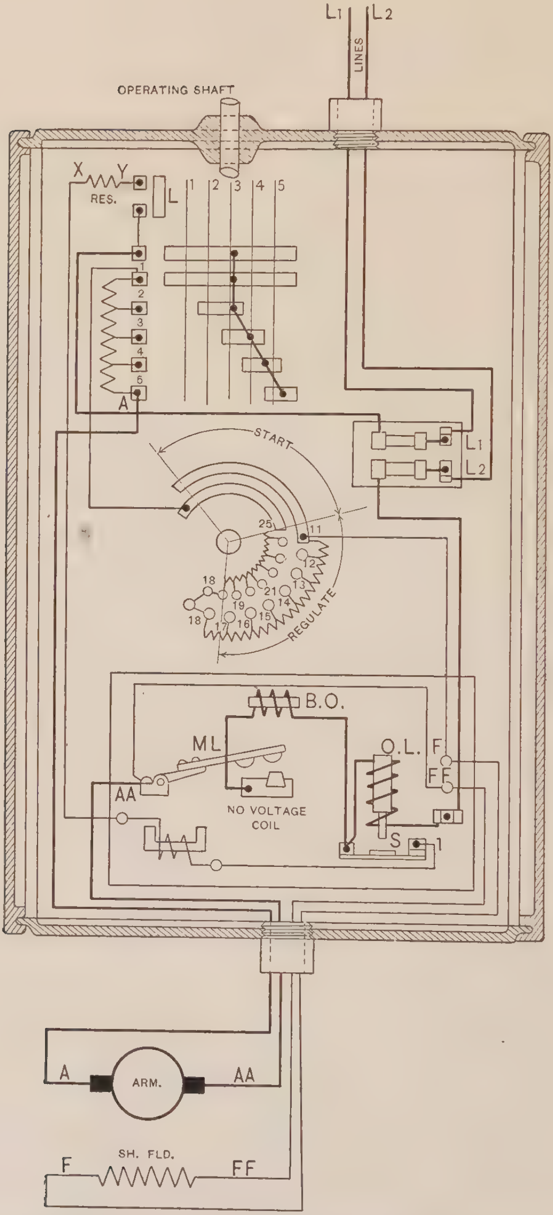

L1
L2
LINES
OPERATING SHAFT
X
Y
RES.
L
1
2
3
4
5
1
2
3
4
6
A
START
L1
L2
25
11
12
13
14
15
16
17
18
19
21
18
REGULATE
B.O.
ML
O.L.
F
FF
AA
NO VOLTAGE COIL
S
1
A
ARM.
AA
SH. FLD.
F
FF

Fig. 115.—Turret Blower Controller. Wiring Diagram. Cutler-Hammer Co.

ning positions the hand may be removed from the auxiliary lever and the controller will remain on any of the running points.

To start the motor it is necessary to first move the small lever controlling the pilot switch L through a small angle to close the circuit to the no-voltage release magnet. This circuit is made from the L_2 side of the line at 1 through the no-voltage coil and resistance XY across the switch L to the L_1 side. This energizes the no-voltage coil which holds the main-line switch ML closed after it has been closed by the controller. After the pilot switch has been closed, the starting lever is moved in the usual manner which first closes the motor through all the armature starting resistance and then a continuous movement cuts out the starting resistance in the armature circuit. In the position in which all armature resistance is out of circuit, the pilot switch is held closed by a cam on the controller shaft and the starting arm may then be moved at will to any of the succeeding field-control positions.

The field is energized by the circuit from AA on the hinge side of the main switch to the terminal FF through the field to terminal F and to the outer segment to which the field resistance units are connected.

The operating shaft of the controller carries an arm at its lower end with two brushes, electrically connected, that move over the two rows of contacts and segments.

The field circuit is completed across these segments to terminal 1 of the starting resistance and to the L_1 side of the line. Continued motion of the starting arm after the drum cylinder has been revolved to cut out all the starting resistance moves the contact points over the rows of button contacts to which the resistance units are connected. Current then for the field instead of flowing directly from one segment to the other must flow through the resistance units, of which two are added in series with the field circuit for each successive position of the arm carrying the contact points. When the last position is reached all the field resistance is in circuit and the motor runs at its maximum speed.

If the line voltage fails, the no-voltage magnet is de-energized, and the main switch, being no longer held, opens, breaking the main circuit. The main switch will remain open even if the line voltage is restored unless the starting arm is moved to the "off" position.

Overload.—In case of overload, the plunger in the overload solenoid opens the switch S, which breaks the circuit of the no-voltage coil, which being de-energized allows the main switch to open.

In case of either failure of voltage or overload, the main-line switch can only be closed by the restoration of the line voltage and by moving the controller handle to the "off" position.

FIRE ROOM FORCED-DRAFT BLOWER SYSTEM.

Controlling Appliances.—This apparatus consists of a series of contactors, which are remotely controlled from the fire room, and is such that the fans for the forced-draft system can be automatically started, stopped and adjusted for speed from the fire room, the fans themselves being installed in a remote blower room. No manual operation in the blower room is required, but provision is made for stopping the fans there in case of emergency, and also for starting them from the same point.

The diagram of electrical connections is shown in Figs. 116 and 117. The contactor panel, shown on the right (Fig. 116), is installed in the blower room. It is enclosed in a watertight case provided with removable sheet metal cover, made watertight by means of rubber gaskets and clamping devices. The small master controller, shown on the left, is located in the fire room. It contains the field resistance and all the necessary contact points for controlling the speed of the motor and the necessary contacts for starting and stopping the automatic controller in the blower room. It is enclosed in a watertight casing with removable cover made watertight by rubber gaskets and clamping devices.

The diagram shows five contactors, 1, 2, 3, 4 and 5. Three of these contactors, 1, 2 and 3, are of extra heavy capacity, as they handle all of the line current continuously, while 4 and 5 are used for cutting out the starting resistance and are of smaller capacity, as they are only in circuit during the time the motor is accelerating. Contactors 1 and 2, in conjunction with an adjustable overload relay device, form an automatic double-pole circuit breaker. The overload relay is provided with a holding coil so that in case of overload the plunger of the overload relay is returned to its normal condition only when the master controller in the fire room has been thrown to the "off" position.

The master controller is operated by a hand wheel on a small shaft projecting through a watertight stuffing box, and the starting and stopping of the blower, all speed control, and resetting of the circuit breakers are accomplished by the rotation of this hand wheel.

To start up the blower equipment it is simply necessary to turn the hand wheel from its "off" to the first running position and the motor will immediately come up to normal speed by means of the automatic controller in the blower room. Succeeding movements of the hand wheel will obtain any desired increase in speed up to the full-speed position. In case of overload, it is simply necessary to return the hand wheel to the "off" position, when the blower may be again started by moving the wheel to the running and succeeding speed positions.

The speed variation is obtained by changes of resistance in the field circuit of the motor. To prevent the blower operating at full speed under entirely unrestricted air conditions, a current relay, marked 6, is provided, whose function is to lift its plunger at a predetermined value of current, which operates contactor 7, short circuiting the motor field resistance. This limits the load to that obtaining under normal motor speed. In order to reset the load relay and obtain the higher speeds it is necessary to return the master controller to the first running position and then gradually speed up the motor by turning the hand wheel to succeeding speed positions.

METHOD OF OPERATION.—When the handle of the master controller is turned to the first or starting position, circuit for closing the contactors 1 and 3 is made as follows: Current flows from line LL at M through the lower discs of contactors 4 and 5, the lower disc of contactor 2, where it divides, part flowing through the coil of contactor 1 and part through the coil of contactor 3. These currents unite at the lower terminal of coil 3 and then flow through the switch S to terminal PP. From here current flows to terminal PP in the master controller through arm to P′, to P′ in the push button, to P in the push button, to P in the contactor case and to the line L. This energizes the coils of contactors 1 and 3 and they close.

The motor field is energized as follows: Current flows from line LL at N to terminal FF″, to terminal FF″ in master controller, through arm to FF′, to FF′ in contactor case, to FF, through the field to F and to line L at A. This gives normal field strength.

When contactors 1 and 3 close, the main current flows from line LL through contactor 1, through relay 6 and series relay 1, armature resistance R to AA, through armature to A, and overload coil OL, through contactor 3 to line L. When contactor 1 closes, it raises its plunger and its disc completes the circuit between the two posts above it. When the first rush of current takes place, series relay 1 lifts, but when the current has fallen, due to generation of counter E. M. F., it drops, closing the circuit between the posts below it. When this takes place, current flows from line LL at O, through the middle of contactor 2, across the disc of contactor 1 and the disc of series relay 1 to the upper terminal of the coil of clapper 4. From here current flows through the coil to the lower terminal of the overload coil OL, to line L through contactor 3. Clapper 4 now closes, and in doing so breaks the circuit at its lower disc, and the feeding circuit to contactors 1 and 3. These remain closed, however, as they get current from line LL through the resistance CD, and will remain closed though they would not close on the small current that would flow through CD.

When clapper 4 closes, the main current takes the same path as before, but does not flow through series relay 1, but through clapper 4, series relay 2 and resistance R′, and thence as described above. Resistance R′ is of less value than R and the current takes the path of least resistance. When current flows through clapper 4, there is a second rush of current and series relay 2 lifts. When the current falls again, due to counter E. M. F. at the increased speed, the relay drops and closes the circuit between the two posts. When clapper 4 closes, it makes contact with the left-hand post under the series relay, and positive potential is then fed from the clapper to the upper terminal of the coil of clapper 5 and current flows through this to the line L, as described above, for clapper 4. Clapper 5 then closes. When it closes, the main current takes the path above described, but does not flow through clapper 4, but through clapper 5, series relay 3, and the resistance R″, as R″ is less than R′, and then as detailed above to line L.

When clapper 5 closes, there is another rush of current and its series relay 3 lifts. When the current has fallen to a predetermined amount, the relay drops and makes circuit across the posts below it. When clapper 5 closes, it makes contact with the left-hand post under the series relay and positive potential is fed from the clapper to the upper terminal of the coil of contactor 2 and current flows through this to the line L by way of the overload coil OL and contactor 3.

When contactor 2 closes, the main current flows from the lower terminal of clapper 5 through contactor 2 and thence, as previously described, under which condition all starting resistance is out of circuit and the motor comes to full speed. When contactor 2 closes, its plunger lifts the three discs above it. This breaks the circuit through the middle disc and the disc of contactor 1, which feeds the coil of clapper 4. Consequently, clapper 4 opens, and, in opening, it opens the feed circuit of clapper 5, which opens, and it in turn opens the feed circuit to contactor 2, which, however, does not open, as it is now fed directly from the main line through the resistance AB. This contactor will remain closed on less current than it takes to close it, and ordinarily not enough current would flow through AB to close it.

All the above-described operations take place when the master controller is moved to the starting or normal speed position, and the motor comes quickly up to speed under normal field strength. Moving the arm of the master controller beyond the first position gradually inserts resistance in the field circuit and the motor speeds up.

In case the load is suddenly decreased to prevent the blower operating at full speed, at a predetermined value of line current, series relay No. 6 lifts its plunger, when current flows from line LL through the disc and through the coil of contactor 7 to terminal, to R in the master controller and back to the other side of the line by way of P′ and P. This causes contactor 7 to close and short circuits the field resistance between FF″ and

FF′ and the motor speed falls to that, due to normal field. Under this condition the relay plunger will drop, but the current through 7 is maintained through the resistance GH and it remains closed. The starting arm in the master controller is then moved back to the first starting position, when 7 opens, due to opening the circuit at R in the master controller, and the higher speeds may again be obtained by moving the arm again to cut-in resistance. Clapper 7 is kept closed, after the relay has fallen, to prevent the increased resistance of the field being suddenly inserted in the field circuit and it remains closed until all resistance is out, after which resistance can be slowly added.

In case of overload, the overload coil OL raises its plunger, which opens the switch S and breaks the operating circuit of the contactor coils 1 and 3, rendering the whole equipment dead. The plunger is held in its raised position by the holding coil above the overload coil, as the circuit is complete from O through Y, the holding coil to PP and to P, to line L. Returning the master controller handle to the "off" position breaks the circuit of the holding coil, and switch S falls, putting the equipment in a position to be again started.

In addition to the control obtained from the fire room, a watertight push-button station is provided in the blower room by means of which the fan may be stopped and started, this control being independent of the fire-room master controller. This push-button station is shown to the left on the wiring diagram. It consists of a metal case and removable cover made watertight by means of packing and clamping bolts and stuffing boxes for the operating push rods, and contains a cylinder making contact with drum fingers. The fan is stopped regardless of the position of the fire-room master controller by depressing the "stop" button, the cylinder remaining latched in this position. In order to start the fan the "start" button is depressed, which action also releases the latch by means of a cam, so that when the "start" button is released the cylinder is returned to its normal position by the powerful compression spring and the control is again restored to the fire-room controller. The push-button station has all of the functions of the fire-room master controller except speed control.

If the "stop" button is pressed when the motor is running with the handle of the master controller in position for weakened field, the whole equipment becomes dead, and the handle remains in its position. If under this condition, the "start" button is pressed and released, the motor starts again, but with normal speed, as contactor 7 is energized through the R terminal of the master controller and closes and remains closed through resistance GH, after the feeding circuit from O has been opened by contactor 2 lifting the middle disc. To obtain field control after this, it is necessary

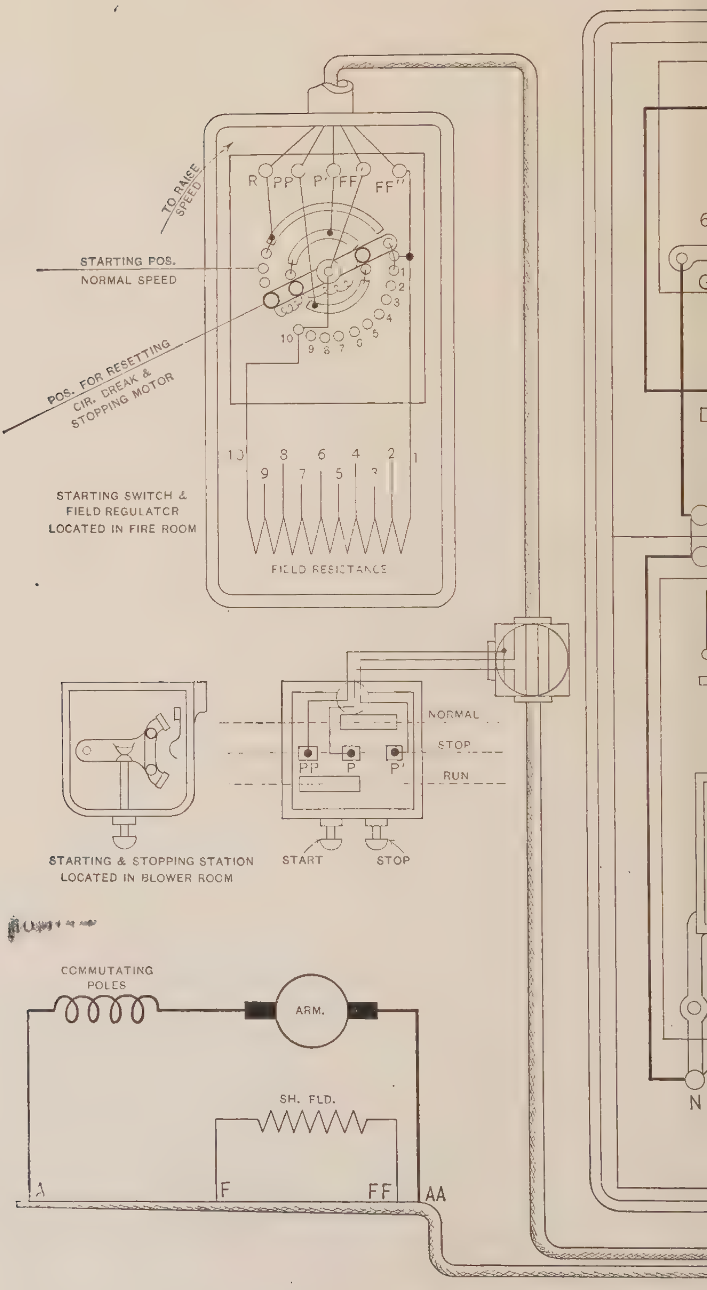
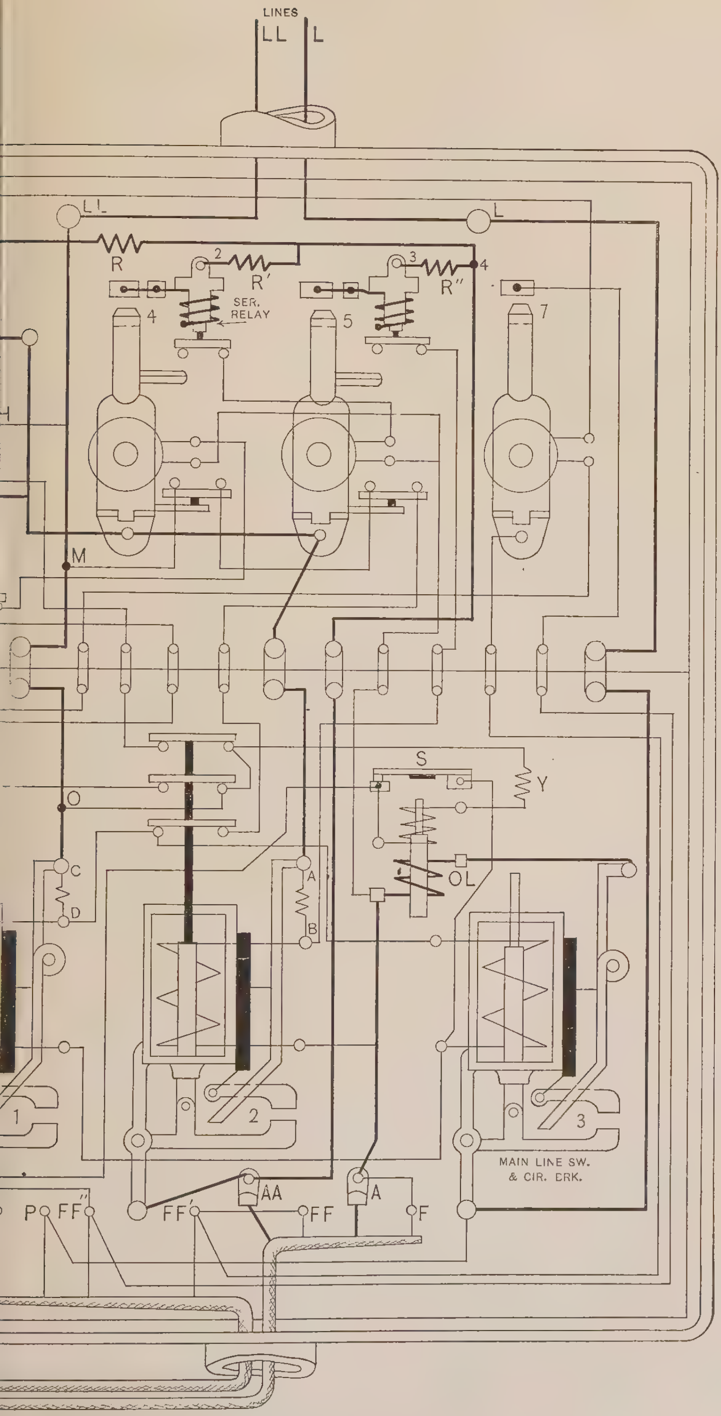

TO RAISE SPEED
R
PP
P'
FF'
FF''
STARTING POS.
NORMAL SPEED
1
2
3
4
5
6
7
8
9
10
POS. FOR RESETTING CIR. BREAK & STOPPING MOTOR
STARTING SWITCH & FIELD REGULATOR LOCATED IN FIRE ROOM
FIELD RESISTANCE
NORMAL
STOP
RUN
PP
P
P'
STARTING & STOPPING STATION LOCATED IN BLOWER ROOM
START
STOP
COMMUTATING POLES
ARM.
SH. FLD.
A
F
FF
AA
6
N

FIG. 116.—Forced-Draft Blower Sys


LINES
LL
L
LL
L
R
2
R′
3
R″
4
SER. RELAY
4
5
7
M
H
O
S
Y
OL
C
D
A
B
1
2
3
MAIN LINE SW. & CIR. BRK.
P
FF″
FF′
AA
FF
A
F

iring Diagram. Cutler-Hammer Co.

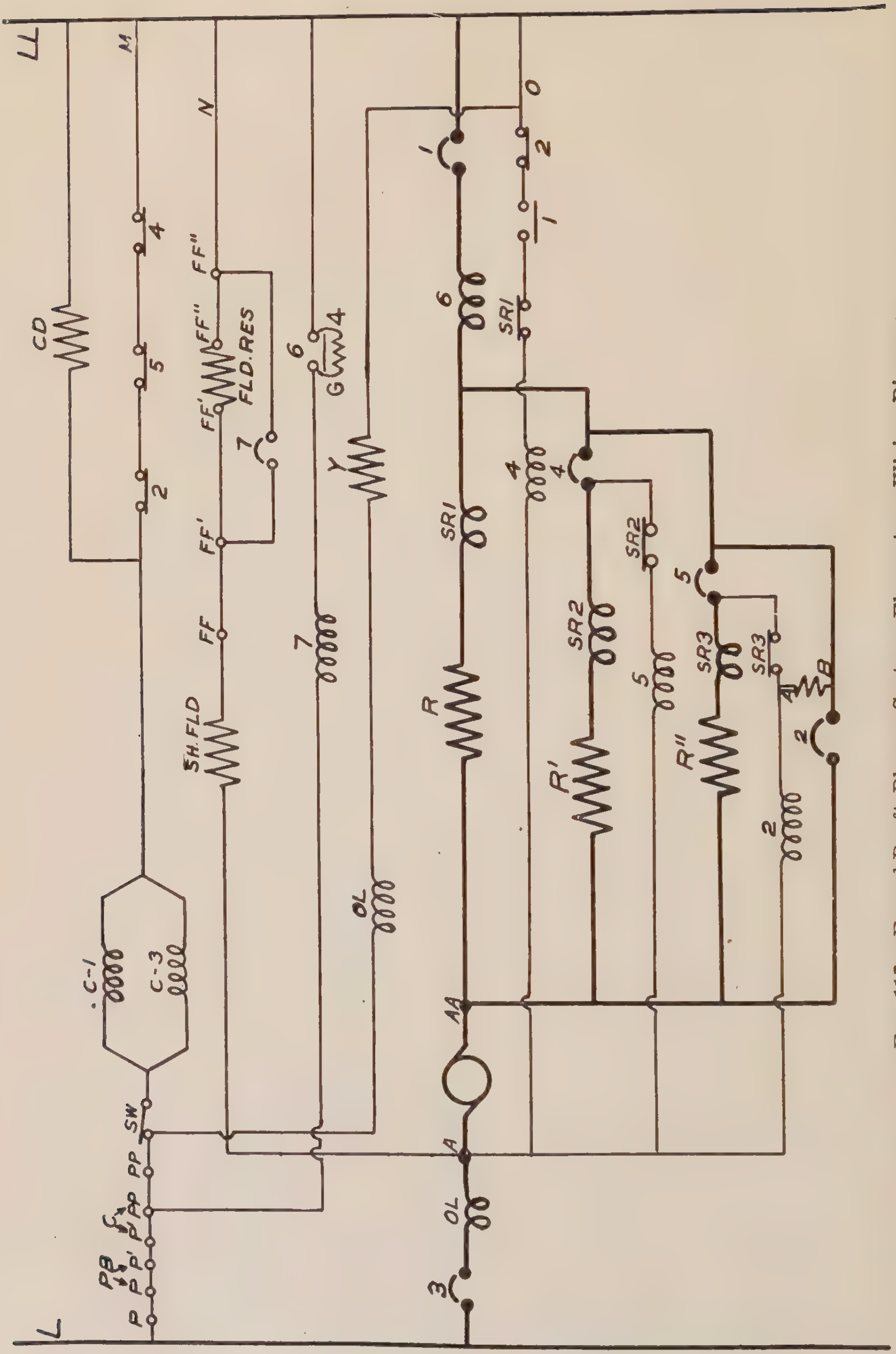

LL
L
M
N
O
CD
2
5
4
FF"
FF'
FLD.RES
7
FF
SH.FLD
6
G
Y
OL
C-1
C-3
SW
PP
P'
PB
P
C
1
2
SR1
R
AA
A
3
SR2
R'
SR3
R"
B

FIG. 117.—Forced-Draft Blower System, Elementary Wiring Diagram.

to return the handle to first running position which breaks the circuit of the operating coil of contactor 7 at R in the master controller and 7 will then open. Moving again the operating handle will give the desired speed control, as 7 will not again close, as its feeding circuit through the middle disc of contactor 2 is now open, and it will not close through the resistance GH.

If, on starting the equipment, the operating handle is moved quickly beyond the first running position, contactor 7 will close, as it will get current from O through the middle disc of contactor 2, before the latter has time to close, and consequently contactor 7 will remain closed, as it gets current through GH. Under this condition variable speed cannot be obtained until the handle is returned to normal position and the motor has come up to speed, after which variable speed can be obtained in the usual manner. This action is more or less an automatic protective device to prevent weakened field until the motor is up to speed.

MACHINE TOOLS.

Machine tools are now usually driven by independent motors. The type of motor, winding, and method of control, are dependent on the service. Most of the motors are of powers under 5 horsepower. Large lathes are the only ones that require more than this power. Makers furnish the types they prefer, providing it meets the requirements. There are many different types of motors and methods of control in use, differing in details and in methods of obtaining the desired results. In nearly all cases, however, they are similar to some of those that have been described.

The Reliance motor, shunt wound, is used for all the tools on the *New York* and on several other ships. It has already been described (Chapter III).

The type of control described on page 135 for TURBINE-TURNING EQUIPMENT is frequently used for machine tools.

BOAT CRANES.

On the latest battleships boat cranes are built to handle loads of 40,000 pounds, and tested with load of 80,000 pounds, which must be handled safely and under complete control at all times.

The machinery is mounted upon a cast-steel platform encircling the crane post and supported by 24 steel rollers in a cast bearing bolted to the crane pillar. The inner face of the platform carries two white metal rings as steady bearings between platform and the crane pillar. An internal rack with cut teeth extending all the way around is supported by brackets from the crane pillar just below the machinery platform.

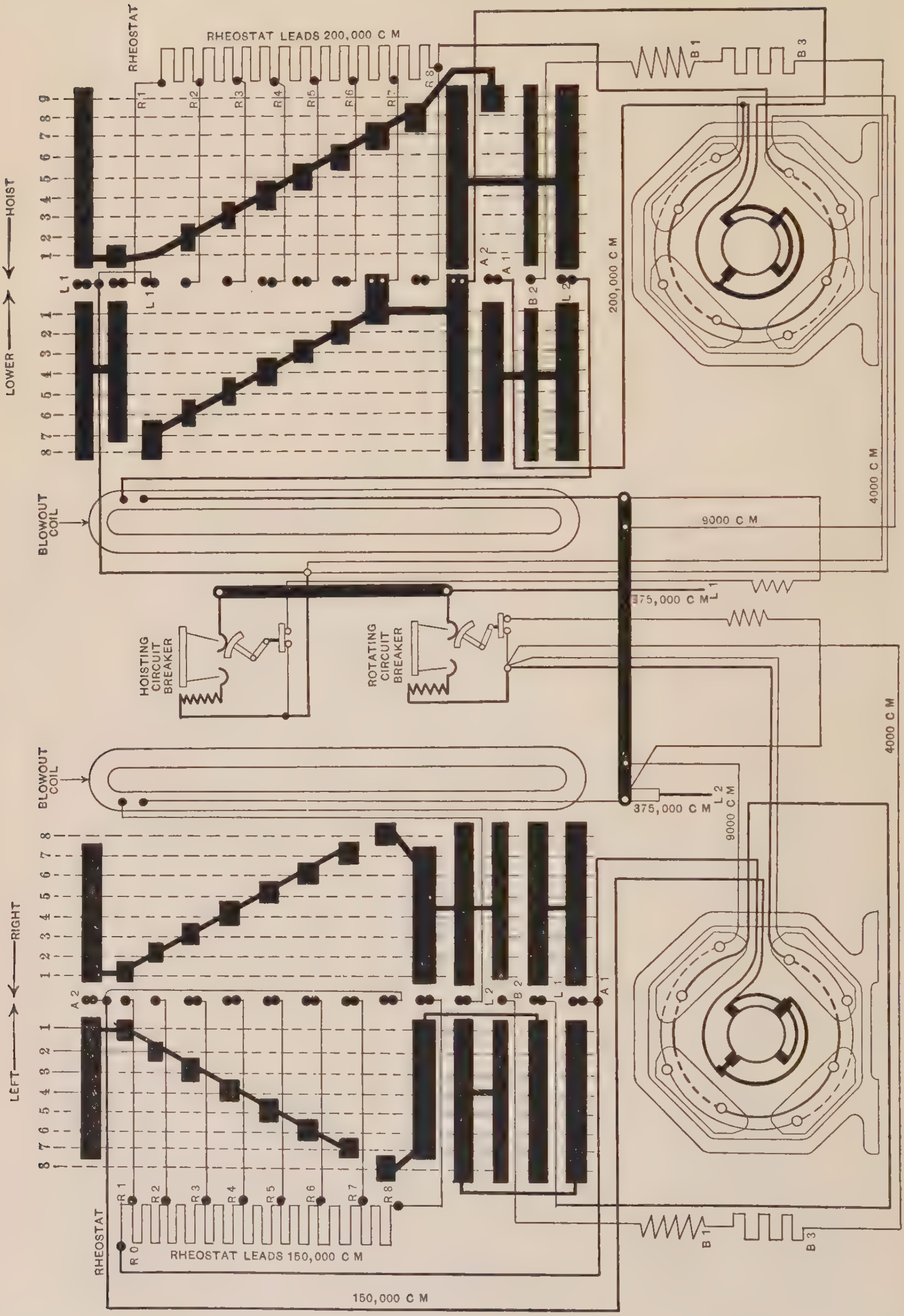
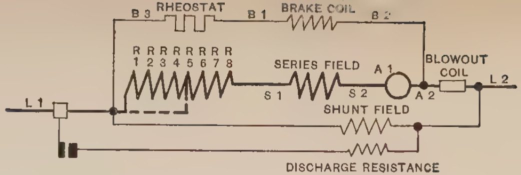
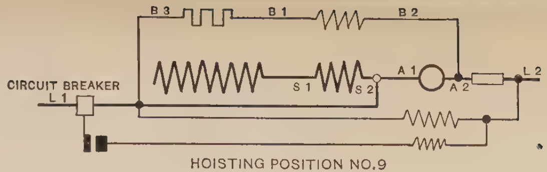

RHEOSTAT
RHEOSTAT LEADS 200,000 C M
R 1
R 2
R 3
R 4
R 5
R 6
R 7
R 8
HOIST
LOWER
L 1
A 2
A 1
B 2
L 2
B 1
B 3
200,000 C M
4000 C M
9000 C M
BLOWOUT COIL
375,000 C M
L 1
HOISTING CIRCUIT BREAKER
ROTATING CIRCUIT BREAKER
375,000 C M
L 2
9000 C M
4000 C M
BLOWOUT COIL
RIGHT
LEFT
A 2
L 2
B 2
L 1
A 1
B 1
B 3
R 0
RHEOSTAT
RHEOSTAT LEADS 150,000 C M
150,000 C M

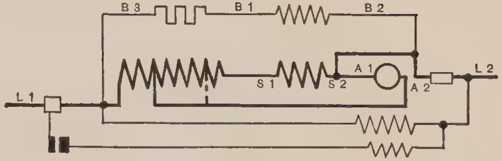
FIG. 118.—Boat Crane, Wiring Diagram.


B 3
RHEOSTAT
B 1
BRAKE COIL
B 2
R R R R R R R R
1 2 3 4 5 6 7 8
SERIES FIELD
A 1
BLOWOUT COIL
L 1
S 1
S 2
A 2
L 2
SHUNT FIELD
DISCHARGE RESISTANCE

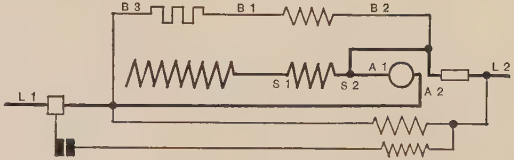
HOISTING POSITION NO.1 TO NO.8


B 3
B 1
B 2
CIRCUIT BREAKER
L 1
S 1
S 2
A 1
A 2
L 2

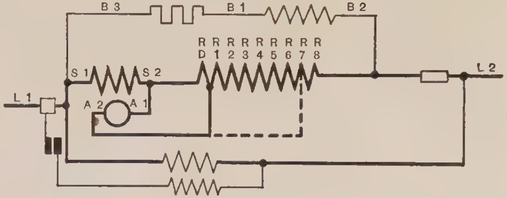
HOISTING POSITION NO.9


B 3
B 1
B 2
L 1
S 1
S 2
A 1
A 2
L 2

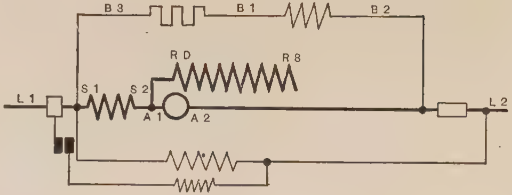
LOWERING POSITION NO.1 TO NO.7


B 3
B 1
B 2
L 1
S 1
S 2
A 1
A 2
L 2

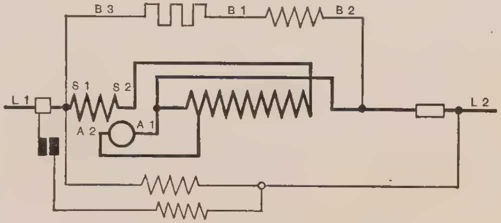
LOWERING POSITION NO.8


B 3
B 1
B 2
R R R R R R R R R
D 1 2 3 4 5 6 7 8
S 1
S 2
L 1
A 2
A 1
L 2

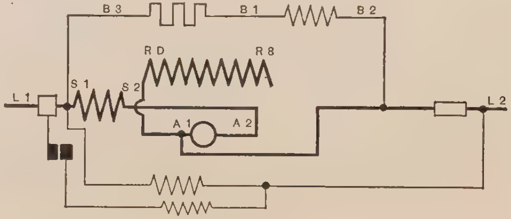
ROTATING RIGHT HAND POSITION NO.1 TO NO.7


B 3
B 1
B 2
R D
R 8
S 1
S 2
L 1
A 1
A 2
L 2

ROTATING RIGHT HAND POSITION NO.8


B 3
B 1
B 2
S 1
S 2
L 1
A 2
A 1
L 2

ROTATING LEFT HAND POSITION NO.1 TO NO.7


B 3
B 1
B 2
R D
R 8
S 1
S 2
L 1
A 1
A 2
L 2

ROTATING LEFT HAND POSITION NO.8

FIG. 119.—Boat Crane, Elementary Diagram.

REQUIREMENTS.—The requirements of the electrical equipment are:

(1) Large starting torque, to be capable of taking full load instantly, as lifting a boat from the cradle or from the water, and of withstanding sudden large variations of load.

(2) Smooth starting and stopping and changes of speed are required under all conditions. Stopping must not be abrupt enough to cause whipping of crane head or dangerous swinging of the load.

(3) Surging in speed of rotation due to swinging of load must be prevented, as must acceleration when rotated in direction of heel of ship.

(4) Hold maximum load and not allow lowering while controller is in any hoisting position.

(5) By no combination or manipulation of operating lever, opening of circuit breaker, or failure of current may load be allowed to fall.

(6) Load must stop and be held when operating lever is brought to "off" position from any other position.

(7) Brakes must be of sufficient power to stop and hold maximum load.

MOTORS.—There are two motors, one for hoisting and one for rotating. They are duplicates, enclosed, cumulative compound wound (in earlier ships, series wound), 50 horsepower for large ships, fitted with electric magnetic disc brakes.

The hoisting motor drives, through gearing, the drum that carries the hoisting rope. The rotating motor, through gears and a worm and worm wheel, drives a pinion that engages the internal rack secured to the crane pillar.

CONTROLLING APPLIANCES.—There are two separate drum controllers, one for rotating and one for hoisting, contained in the same casing, which also holds a panel on which are mounted the contactors, circuit breakers, automatic resetting devices and the magnetic blowouts. Each circuit breaker is provided with an auxiliary contact so arranged that a discharge resistance will be connected across the shunt field when the circuit breaker is open.

OPERATION.—(See wiring diagram, Fig. 118, and elementary diagrams, Fig. 119.)

Rotating.—The rotating motor is compound wound and is operated in both directions on the Day system of control, there being eight points for all speeds in both directions with the series field always in. This system of control consists in connecting a rheostat across the line, with the armature in multiple with a section of the resistance. The speed is increased by increasing the amount of resistance in multiple, thereby increasing the drop across the armature. Under ordinary conditions the machine will run as a motor.

In case, however, there is a heavy sea causing the ship to roll heavily, the pitch of the crane may cause the motor to be overhauled acting as a generator. The resistance in multiple will then act as a brake preventing the speed rising to an excessive amount.

To start the rotating motor, say to the left, the lever is thrown over to the first contact point (Fig. 118). Current flows from line L1, through circuit breaker, to series field, to contact finger L1, through controller rings to R8, through resistances to R1, through controller rings to A2 at top, through armature to A1 connection at bottom of controller, controller ring, to L2, through blowout magnet to L2. From R1 a connection leads to RO, to A1, in multiple with the lead through the armature. By turning the controller further, making contact with R7, R6, etc., it can be seen that resistance is cut out of the armature circuit and into the circuit in multiple with the armature.

When the controller is turned to position No. 8, the multiple circuit is disconnected and the operation is that of a compound-wound motor.

The circuit breaker operates as a no-voltage and overload device.

Hoisting.—For hoisting, the motor is operated on straight rheostatic control. In position No. 9, however, the series field is cut out to obtain high speed with empty hook.

Lowering.—In lowering, the series field is connected in multiple with the armature always acting cumulatively. When lowering a heavy load, the armature may be overhauled, acting as a generator loaded on the series field and more or less of the rheostat under conditions similar to that of the rotating motor. In the first position for lowering, the current flows from line L1, through circuit breaker to contact L1, through resistances to R7. Thence one circuit, R8, through series field, to A1, on controller to L2, and to line L2. From R7 another circuit through controller rings to A2 on controller, to armature, to connection with series field, to A1, etc. The elementary diagram shows the action clearly. On the successive positions resistance is cut into the circuit with the series field and out of the multiple circuit until position No. 8. In this position the circuit from L1 through resistances and series field is broken and current flows from contact L1, through controller segment to A2, through armature to A1 and to line, cutting out the series field, allowing high speed to be obtained.

No. 8 lowering and No. 9 hoisting positions are used only with empty hook. A small handle on the outside of the controller operates, through a cam, an adjustable stop that prevents the controller cylinder from being thrown over to these positions. When this handle is thrown over, the controller cylinder can be moved past the stop to these positions. A spring forces the stop back into the normal position, as soon as the controller is thrown back into one of the other positions, and the hand is removed from the small handle. The brake circuit is shunted across the line as shown.

The brake is of the electric disc type; operates when current is off, and releases when current is on.

There are mounted inside the controller frame two discharge resistance units for the shunt fields, one for each motor.

The boat-crane motors described are installed on the *Nevada*. On later ships the same type of motor and the same principles apply. The contactor type of controller is used on some later ships. On the *New York* and all ships built prior to that vessel the motors were *series* wound. The general principles of the operation are similar to the ones described.

CHAPTER VII.

APPLICATIONS OF MOTORS (Continued).

TURRET-TURNING EQUIPMENT.

There are in use at the present time four systems to electrically control the turning of turrets of our ships of war. They are generally referred to as

(I) **Ward-Leonard System.**
(II) **Motor-Generator System.**
(III) **Differential System.**
(IV) **Hydraulic Speed-Gear System.**

In whatever system used the control of the turret must be maintained throughout the full arc of fire and will be as follows:

(1) The turret shall be capable of being trained to full speed in either direction from full speed in the opposite direction in two seconds or less.

The minimum rate of turning shall be about $\frac{1}{4}°$ per minute and the maximum rate about 100°, but not less than 95° per minute, and the changes in speed throughout this range shall be without abrupt or perceptible steps.

(2) The turret shall be capable of being started five times in an arc of five minutes of train.

(3) The turret shall be capable of being turned against a 200 tons-feet resistance (simulating a jammed turret). The drift of the turret shall not exceed 1° when the controller is thrown suddenly to the "off" position or circuit breaker tripped with turret moving at full speed. The power speed gear shall be direct connected to the worm shaft without intermediate gearing.

(4) At all speeds between and including the minimum, the turret must turn continuously through any position of the arc of train in each controller position with practically no variation in speed due to the increased load on the motors caused by allowable irregularities of track, gearing, etc.

Complete duplicate units of motors and mechanical gears are installed in each turret, either of which may be connected to the cross shaft, the other being disconnected and held in reserve.

I. Turret Turning—Ward-Leonard System.

PRINCIPLES OF OPERATION.—This method of control depends upon the fact that *the speed of a motor armature running in a constant magnetic field is proportional to the volts impressed upon the brushes.* Therefore, by conveniently varying this voltage, the speed is varied. To accomplish this an independent generator for the supply of the turning motors is required. The armature terminals of the generator are directly connected to the armature terminals of the motors. The field of the motor is excited from the switchboard bus bars providing the constant field. The shunt field of the generator is separately excited from the bus bars, and is controlled by a rheostat operated by a controller in the turret. The series field of the generator is shunted.

As the engine drives the generator armature at a constant speed, the volts delivered by it to the motor armatures are approximately proportional to the shunt field excitation. In this way the speed of the motor armatures and of the turrets is directly controlled over a wide range by the operator in the turret.

This statement is correct regardless of the mechanical resistance encountered up to the load which causes the engine to materially slacken speed.

GENERAL ARRANGEMENT.—The series field is shunted, but not entirely cut out, so that it acts as a shunt field of few turns and has a slight effect in building up the voltage of the generator so that the turret may start more promptly than if it were dependent on the separately excited shunt field alone.

The current required is dependent upon the turning moment necessary to overcome the mechanical resistance and will not vary greatly at any constant speed, regardless of what that speed may be.

While an independent generator is required, the switchboard is so designed that any one of the several generators may be used for any turret. The field rheostat of the designated generator is cut out and the rheostat in the turret controller connected in.

The circuit is so arranged that either motor may be electrically cut out and the other motor be operated to the extent of its capacity.

The *controller,* in addition to operating the generator field rheostat, also controls current to the motor armatures in the direction to give the rotation required.

There is an ammeter in each armature circuit, so that it may be known when either motor is running under unusual load. An automatic circuit breaker opens the armature circuit of both motors in case of an overload.

The brushes of the motors and the generator are connected by the armature leads and are independent of all other connections.

The field of the generator is separately excited from the constant potential bus bars, and this circuit is extended to the rheostat located in the turret. The motor fields are also excited from these bus bars.

The reason for separately exciting the generator field is to cause it to respond immediately to a change of the rheostat and thus avoid the delay required in building up a self-exciting generator. The motor fields are separately excited in order to give a constant excitation, which could not be obtained from the driving generator, as the pressure at the motor brushes will vary according to the desired speed.

Thus the person operating the rheostat controls the speed of the motor, which will remain constant at any point until the resistance is changed.

In the actual installation the same hand wheel which controls the rheostat also controls the direction of rotation of motor, so that the operator who is training the turret has complete command of the direction and speed of movement.

CONTROLLING APPLIANCES.—A drum controller of the P type, previously described, is mounted in the turret. A panel below the turret floor carries the switches, two ammeters and circuit breakers.

Electrical Connections.—Fig. 120 shows the entire connections of the system in which one main generator is used to turn a turret, as originally installed.

The armature connections of the motors are brought to the fingers connected with the second wide segment from the bottom after having passed through the "blowout" coil and the fingers connecting with the upper wide segment. The main lines are brought to the binding posts attached to the fingers of the two remaining wide segments. From each one of the main lines and armature leads, is branched a circuit through an auxiliary rheostat, and connected to the single fingers. It will be noted that the auxiliary contacts are longer than the main segments, so that in rotating the cylinder in either direction from the "off" position, the auxiliary segments touch their corresponding fingers a little before the main segments make connection, and breaks the connection later when the controller is being turned off. This provides a gradual making and breaking of the main circuit in the operation of the controller, and reduces the amount of arcing that would occur at the main segments if the auxiliary segments were not used.

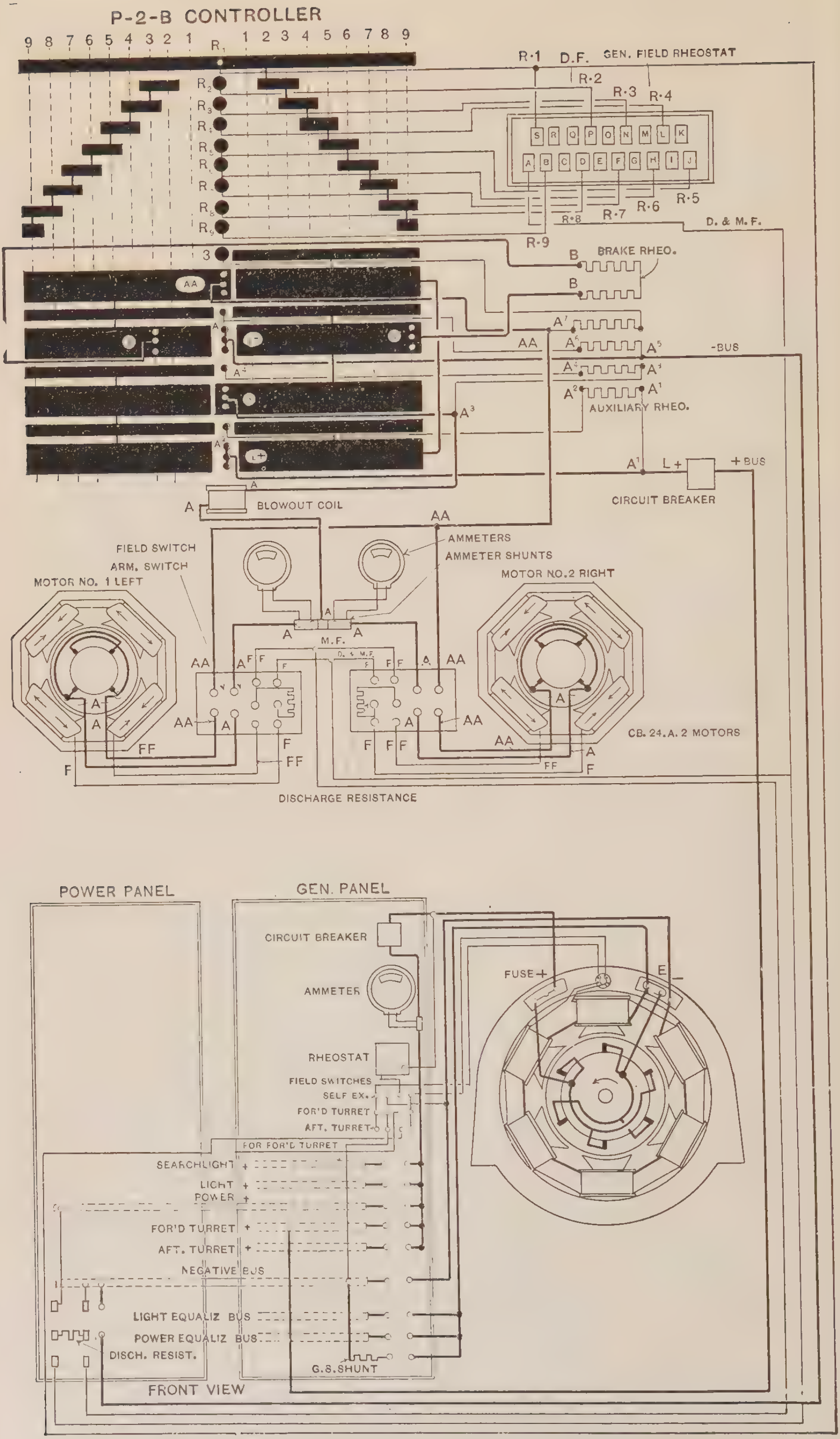

P-2-B CONTROLLER
9 8 7 6 5 4 3 2 1 R1 1 2 3 4 5 6 7 8 9
R2
R3
R4
R5
R6
R7
R8
R9
3
AA
A
A4
A2
A
R·1
D.F.
GEN. FIELD RHEOSTAT
R·2
R·3
R·4
S R Q P O N M L K
A B C D E F G H I J
R·5
R·6
R·7
R·8
R·9
D. & M. F.
B
BRAKE RHEO.
B
A7
AA
A6
A5
-BUS
A4
A3
A2
A1
A3
AUXILIARY RHEO.
A1
L+
+BUS
CIRCUIT BREAKER
A
BLOWOUT COIL
AA
AMMETERS
AMMETER SHUNTS
FIELD SWITCH
ARM. SWITCH
MOTOR NO. 1 LEFT
MOTOR NO.2 RIGHT
A
M.F.
A
D. & M.F.
AA
A F F
F
AA
A
F
FF
FF
F
A
AA
A
F
F F
AA
CB. 24.A. 2 MOTORS
DISCHARGE RESISTANCE
POWER PANEL
GEN. PANEL
CIRCUIT BREAKER
AMMETER
RHEOSTAT
FIELD SWITCHES
SELF EX.
FOR'D TURRET
AFT. TURRET
FOR FOR'D TURRET
SEARCHLIGHT +
LIGHT +
POWER +
FOR'D TURRET +
AFT. TURRET +
NEGATIVE BUS
LIGHT EQUALIZ BUS
POWER EQUALIZ BUS
DISCH. RESIST.
G.S. SHUNT
FRONT VIEW
FUSE +
E
−

FIG. 120.—Ward-Leonard System. Wiring Diagram.

Operation.—By means of the switches shown, either motor may be cut out and the other operated to the extent of its capacity. When the controller is placed in the "off" position, the brushes of the motors are connected through a low resistance so that the armature would generate large currents, if revolved, thus requiring a great expenditure of energy which would be further increased by the mechanical connections from the turret, and thus electrically lock the turret. This condition does not hold unless the motor fields are excited.

When the cylinder rotates on the first position the main connections have been made and the current passes as follows: From the switchboard through the circuit breaker, to the lowest finger, to contact segment, to the lead to the motor armatures, through the switches and motor armatures, and back to the other side of the generator armature circuit through the second wide segment from the top. At this time the field of the generator is separately excited through the field rheostat which is connected to the controller, the leads of which are marked R1 to R9. While this rheostat is in the field circuit, the potential of the generator is at a minimum, but on turning the controller cylinder to the second position, the section R1 to R2 of the rheostat is short circuited, the field current thereby increasing and the potential of the generator being raised, which, of course, increases the speed of the motors.

The further rotation of the cylinder short circuits more of the field rheostats, until on the 9th or last position, the entire field rheostat is short circuited, and the potential of the generator reaches its maximum.

On returning the cylinder to the "off" position, the field rheostat is again connected in the field circuit, reducing the potential of the generator, and therefore the speed of the motor, until just before the "off" position is reached, the main contacts leave their fingers, thus forcing the current to go through the auxiliary rheostat, reducing the current considerably, and when the "off" position is reached, the two main lines are entirely disconnected from the motor armatures, the circuits of the armatures being closed through a brake rheostat by means of triple fingers on the back of the controller, this bringing the armatures to a sudden stop. The circuit is made as follows: Armature terminals to blowout spool, to line segment, to right-hand brake fingers, to brake rheostat, to left-hand brake fingers, to other terminals of armature. The suddenness of the stop of the armature may be regulated by adjusting the brake rheostat.

On turning the controller in the other direction from the "off" position, the same results are obtained except that the direction of current through the armature is reversed, thus reversing its direction of rotation.

If, when the turret is in motion, the controller is turned to such a position that the armature would be driven as a motor at a lower speed than that corresponding to the speed of the turret, the turret will drive the armatures which will immediately generate current and absorb energy, bringing the turret down to the speed of the armatures when running as motors.

MOTORS AND GEARING.—In order to make the understanding of the turret-turning system complete the following description is given of the motor gearing by which the turret is revolved, and as a general guide to the construction of the gearing of all turrets.

There is one motor located on each side of the turret below the floor. They revolve in opposite directions, both driving through bevel gears to one shaft which runs across the turret. This shaft carries at each end a right-hand double-threaded worm, and each worm engages with a worm wheel at the top end of a vertical shaft. At the lower end of the vertical shaft of each of the worm wheels is a pinion which meshes with the circular rack inside of the barbette, thus driving the turret.

The worm wheels are connected to the vertical shafts by friction clutches which can be adjusted by nuts above to carry the desired load, but to slip if it be exceeded, in order to prevent damage to the driving mechanism due to an excessive overload such as would occur when firing one gun, or in the case of impact of a shell on the outside, tending to produce rotation independently of the motors.

These friction clutches consist of 15 flat discs, alternately of brass and steel, the brass discs being loosely keyed to the outer case which is secured to the shaft and the steel discs secured to the inner case which carries the worm wheel, these discs being pressed together by the action of 10 helical springs. These springs are held in the outer casing of the vertical shaft, and their pressure is adjusted by sliding a covering casing along the shaft by means of a large recessed nut and check nut at the top.

The object of the cross shaft is to allow one motor to revolve the turret by driving both pinions should the second motor be electrically or mechanically cut out, and also to permit one motor to revolve the armature of the other motor, in case the latter should fail electrically, through the bevel gears instead of through the worm wheel and worm, which would be the case if the cross shaft were not employed.

A Variation of the Ward-Leonard System.

PRINCIPLES OF OPERATION.—In the system just described, if the generator field is maintained constant and the motor field weakened, the motors will increase speed.

In this system, both this method and the one described above are used. In the first part of the motion of the controller the operation is as described above; the motor field is separately excited and constant, while the resistance is gradually cut out of the generator field until it is all out and the generator

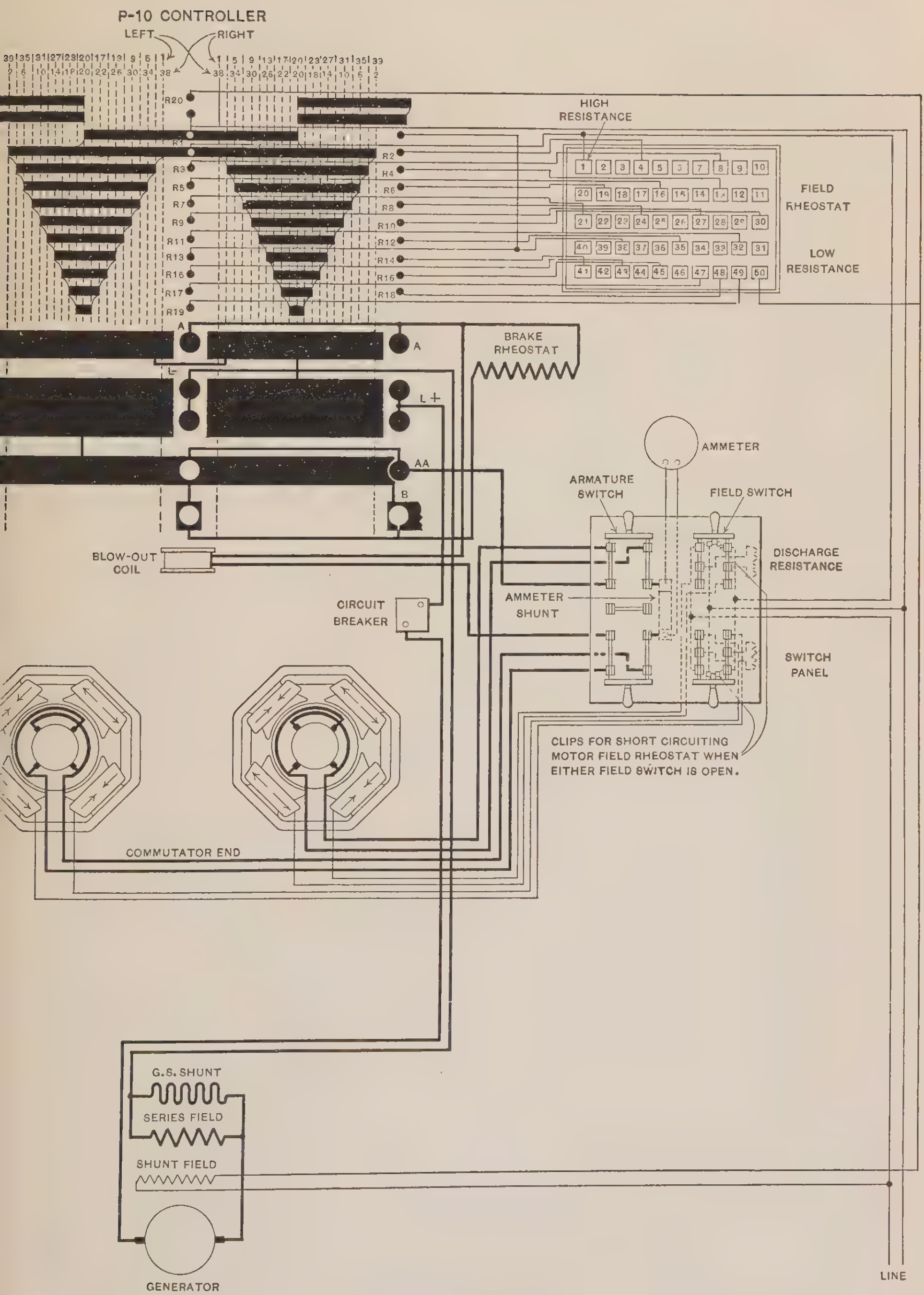

P-10 CONTROLLER
LEFT
RIGHT
R20
R1
R2
R3
R4
R5
R6
R7
R8
R9
R10
R11
R12
R13
R14
R16
R17
R18
R19
HIGH RESISTANCE
FIELD RHEOSTAT
LOW RESISTANCE
BRAKE RHEOSTAT
A
L+
L-
AA
B
AMMETER
ARMATURE SWITCH
FIELD SWITCH
DISCHARGE RESISTANCE
AMMETER SHUNT
SWITCH PANEL
BLOW-OUT COIL
CIRCUIT BREAKER
CLIPS FOR SHORT CIRCUITING MOTOR FIELD RHEOSTAT WHEN EITHER FIELD SWITCH IS OPEN.
COMMUTATOR END
G.S. SHUNT
SERIES FIELD
SHUNT FIELD
GENERATOR
LINE

FIG. 121.—Variation of Ward-Leonard System. Wiring Diagram.

is delivering maximum voltage. In the second part of the motion of the controller, the generator field remains constant with all resistance cut out, and resistance is gradually inserted in the motor field circuit, weakening that field and further increasing the speed of the motors.

Another difference from the first method is that the motors are in series instead of in parallel.

A wiring diagram is shown in Fig. 121 and a cut of the controller in Fig. 122.

ELECTRICAL CONNECTIONS.—The function of the controller in connecting the current from the main generator to the armatures of the two motors in series is readily seen from the diagram of connections, the armature current in all cases being indicated by the heavy lines. The current through the motor armatures is reversed by moving the contact segments in the opposite direction by the controller handle. It will also be noticed that the motor armature terminals are short circuited through the brake rheostat when the controller is in the "off" position, so if the motors are given any motion independent of the generator current, they will act as generators, which, generating current through the low resistance, will absorb power and bring them quickly to rest.

Current for the generator and motor fields is taken from power lines on the ship as indicated in the lower right-hand corner. This controller is designed to control both the current through the generator and motor fields, and the separate operation is as follows:

GENERATOR FIELD.—Current flows from the left-hand line lead to and around the generator field, thence to the terminal on the controller resistance marked 50. Between each one of these numbered blocks is a resistance. The current flows from block 50 through all the resistances to block 1, from there to the finger contact marked R1, thence to the contact segment over it and from there back to the line lead. This is the circuit in the "off" position and the generator field is excited when the line field switch is closed. As the controller is moved, say to the right, the contact segment on which rests R1, moves to the right and makes contact with R2. This results in short circuiting the resistance from 4 to 1, and the total resistance in the generator field is reduced by that resistance. Further movement to the right brings the contact segments in connection successively with R3, R4, etc., each time cutting out some resistance, until the segment makes contact with R19, when the only resistance in the generator field is that between 50 and 49, and at that time, there is maximum voltage at the generator terminals and the motors are running at their maximum speed due to *constant excitation.* Up to this point, this constitutes the speed control as far as changes in the voltage of the generator, and the voltages impressed on the motor terminals, are concerned.

Any further motion beyond that which connects R19 throws the lower finger of the two above R1 off its contact segment, when the generator field circuit is completed through finger R20 (the rheostat resistance for the generator being completely short circuited), as the upper left-hand contact segment now connects with R20. This segment is connected with the one just below it, and the connection to the return field lead is made through the upper finger of the double fingers above R1.

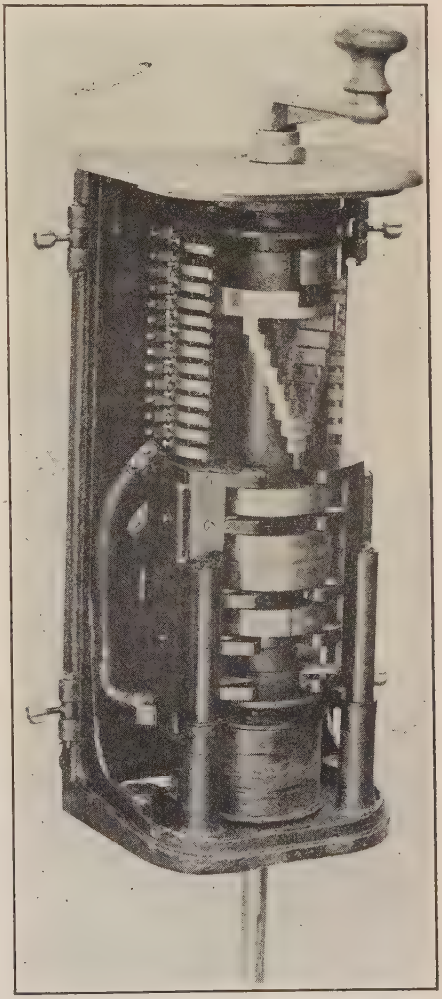


FIG. 122.—P10 Controller for Combined Motor and Field Control.

MOTOR FIELD.—Current flows from the left-hand line lead, as for the generator field, to the left-hand terminal of the three shown between the two motor fields, where it divides, going through and around the fields in parallel, to the right terminal of the three, and thence to finger R1. From here current flows to the contact segment above R1 and then back to the field line lead. This gives constant excitation to the motor fields and it remains constant during the movement of the controller up to the time that the generator field resistance is being cut out; that is, up to the point when the contact finger above R1 leaves its contact segment. At this point, the contact segment is just on R19, when the motor field current from R1 flows through all the contact segments to R19, then to block 49, through the resistance to 50, then to R20, and back to the field line as explained for the generator field.

Any further motion to the right throws R19 off its contact segment increasing the resistance in the motor field circuit to that between 50 and 47. Continued motion to the right, gradually adds resistance to the motor field circuits, weakening their fields and causing consequent increase of speed.

This continues until all the resistance that was cut out of the generator field in the first half of the operation is thrown into the motor fields. This allows a double change of voltage; in the first operation the voltage of the generator increases due to cutting out of its field resistance while the motor fields are constant and in the second operation, the voltage at the terminals of the motors increases due to cutting in resistance in their fields, while the field of the generator remains constant.

The middle terminal of the three between the motor field switches connects to the return side of the field lead.

An inspection of the diagram will show that when the switches are closed, this connection plays no part, as it is broken from the field leads by an insulated clip in the switches, but when either switch is open, the connection indicated by the arrows is made, which has the effect of cutting out, or short circuiting, the controller rheostat, and the turret is then turned by one motor with a constant excitation.

II. Turret Turning—Motor-Generator System.

This system is a development of the Ward-Leonard system, which system requires the sole use of one of the main generators, no matter what reserve power it may have. This is due, of course, to the varying voltage produced at its terminals by variations of the exciting current of its shunt field.

In the motor-generator system, a motor generator is interposed between the main generators and the turning motors, the voltage of the main generator remaining constant, and the remainder of the power may be used on other constant potential circuits.

A constant voltage is delivered by the main generators to the terminals of the motor of the motor generator, and the field of the motor is excited from constant potential mains. The generator armature of the motor generator has the same speed as the motor armature, and its field is varied by a suitable controller and rheostat.

The voltage developed by the generator will depend upon its speed and field excitation, so the voltage delivered to the terminals of the turning motors will be altered by any change in its speed or in its field. The speed will be practically constant and changes in the generator field are made by the controller and rheostat.

CONTROLLING APPLIANCES.—The control is similar to that described under "Ward-Leonard System."

Panel-Type Controller.—There is also a panel-type controller for starting the motor generator. A wiring diagram is shown in Fig. 123. The starting resistance is of slightly different design from any of those previously designed, but presents no new principle, and the connections are easily traced.

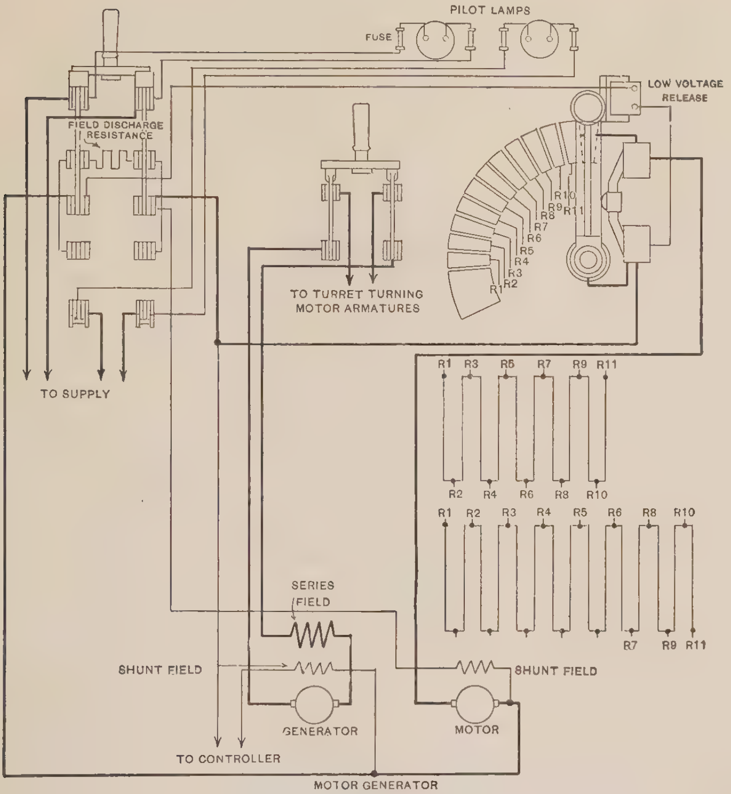

PILOT LAMPS
FUSE
LOW VOLTAGE RELEASE
FIELD DISCHARGE RESISTANCE
TO TURRET TURNING MOTOR ARMATURES
R1 R2 R3 R4 R5 R6 R7 R8 R9 R10 R11
TO SUPPLY
R1 R3 R5 R7 R9 R11
R2 R4 R6 R8 R10
R1 R2 R3 R4 R5 R6 R8 R10
R7 R9 R11
SERIES FIELD
SHUNT FIELD
SHUNT FIELD
GENERATOR
MOTOR
TO CONTROLLER
MOTOR GENERATOR

FIG. 123.—Wiring Diagram. Motor-Generator Sets for Turret Turning. Starting Panel.

III. Turret Turning—Differential-Gear System.

(Cutler-Hammer Manufacturing Company.)

General Description.—The following general description of this method of turret turning has been prepared from data and information furnished by the manufacturers, the Cutler-Hammer Manufacturing Company:

The system consists of a differential set of spur gears entirely enclosed in an oil-tight casing, and operated in a grease bath. This grease bath cushions the noise and reduces the wear of the teeth to a minimum. The upper half of the differential gear case is made readily removable and is provided with a hand hole for inspection and the insertion of grease.

The differential system is operated by two motors, one large and one small one, and each of variable speed. These motors always run in opposite directions and the direction of their rotation is not changed and they are so geared to the differential system of spur gears that the differential shaft always turns in one direction. This differential shaft turns the turret through the agency of a double magnetic clutch and two sets of gears connected to it and to the main turret shaft, one set driving the turret shaft direct, the other through an idler. This effects the reversal of rotation of the turret without change of rotation of the motors as indicated in Fig. 124.

The magnetic clutch, differential gear and reversing gears are mounted on a common bed plate and are connected to the flanges of the motor shafts in the differential case. The motors separately mounted, the small one above the large.

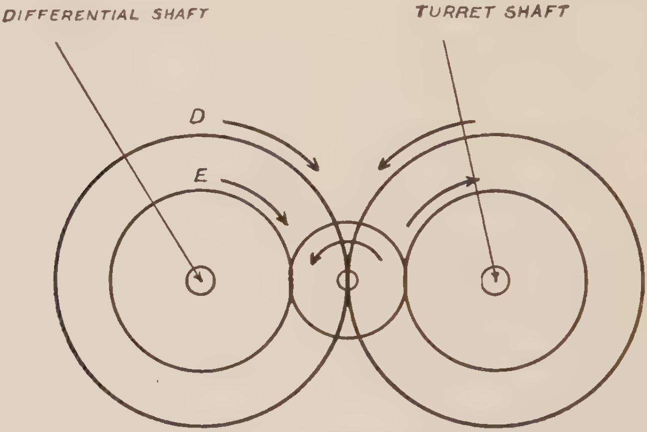


FIG. 124.—Method of Reversal of Turret Shaft.

There are two complete sets of driving units for each turret, each consisting of

Large and small motors.
Differential gear.
Double magnetic clutch.
Reversing gear.
Contactor panel.

Both driving units are controlled by one *master controller,* and either set may be put in operation by a starting or throw-over switch on the controller.

Elementary Principle.—The elementary principle of the differential system is shown in Fig. 125.

The gear A is driven by the small motor and gear B by the large one in opposite directions as indicated. The gears CC are connected to the main differential driving shaft and are also free to turn each around its own shaft. The revolution of CC and in consequence the revolution of the driving shaft will depend upon the relative speeds of A and B, and at one certain relative speed there will be no revolution about the center of the driving shaft, though each of the gears CC will rotate about its own shaft. When this particular ratio of speeds does not exist, CC with its driving shaft will turn, the speed depending upon the relative speeds of A and B. Thus suppose gear B had 72 teeth, gear A 32 teeth, then when the relative speeds of B and A were as 4 to 9, there would be no motion of rotation of the driving shaft, the gears CC simply turning on their shafts. If the speed of A was lowered, CC would take a direction of rotation as shown by the arrow 1, its speed depending upon the ratio of speed of B to that of A.

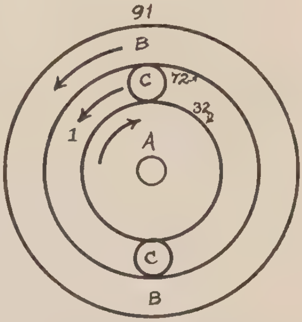


Fig. 125.—Showing Elementary Principle of Differential.

The large motor always carries the turret load and the small motor acts as a speed-regulating device and brake upon the differential and will usually be generating current instead of acting as a motor. The torque furnished by the large motor moves the differential shaft and consequently the turret by the braking effect of the small motor, or, in other words, the torque of the small motor tends to reverse the direction of the turret rotation. If the turret is locked and the differential shaft cannot move, the large motor drives the small one at a high speed and causes it to act as a generator. This is readily seen in the elementary figure. The small motor will always act as a generator when sufficient power is required in driving the turret to cause the large motor to drive the small one through the differential gearing. When the small machine generates current, it is thrown back upon the large motor and the current required from the power lines is approximately only the difference between that required by the large motor and the amount generated by the small one. If the small motor does not rotate, the large motor will drive the turret at a high speed.

Between the extremes of the turret being locked and no revolution of the small motor, or, in other words, under normal conditions, the large motor drives the turret at an intermediate speed, depending upon the torque required. When the small machine acts as a generator the torque required to drive it acts as a brake upon the differential and causes the turret to rotate, due to the difference in torque of the large and small motors. If the required torque is small, or the resistance to rotation is small, the friction of the gears is sufficient to furnish enough braking torque to turn the turret without the small machine acting as a generator; in which case it will then draw from the line only the small current necessary to practically rotate its armature idly. In case the turret load is entirely removed, the small machine would act as a motor entirely and help to overcome the friction of the gears.

Magnetic Clutch.—As has been stated, reversal of the turret is accomplished by a double magnetic clutch operating a set of reversing gears, and in the off position of the turret controller both sides of this clutch are de-energized, thus entirely disconnecting the driving gears from the main-turret driving shaft, although the motors and differential may be still operating at full speed. The clutch consists of a central body containing the two coils and is rigidly keyed to the differential shaft. The armatures of the clutch are secured by cap screws to their gears, which turn idly on the shaft when the coils are de-energized. The side thrust of the gears against the central portion of the clutch is taken up on bronze collars. When either one of the clutch coils is energized, its armature is attracted and held fast and the torque of the driving shaft is then transferred to the turret shaft through the corresponding gears, while the other gear and corresponding armature turns idly on the shaft.

The central portion of the clutch, its pole pieces and gears are of steel, as well as the discs holding the armatures to the gears, and the armatures themselves are cast iron to form a bearing surface against the steel poles. Three bronze collector rings are securely bolted to the central body and the pole pieces extend slightly beyond the surface of these rings and afford mechanical protection. A sheet metal casing extends over the whole clutch and prevents mechanical injury to the clutch or accidental short circuiting of the collector rings or brushes. The leads from the coils to the collector rings are made watertight through the clutch casings.

Motor Operation.—The large motors, which, in the case of 12″ turrets are 25 horsepower and of the 8″ turrets 15 horsepower, have a speed variation of about 2 to 1 by field control. The small motors for 12″ turrets are 10 horsepower and for 8″ turrets are 5 horsepower and they have a speed ratio of 3 to 1 by field control. The large motors operate from 400 to 800 R. P. M., the small motors from 300 to 900 R. P. M. The gearing within the differentials has approximately a ratio of 2¼ to 1, corresponding to the relative speeds of 400 and 900 R. P. M. This is seen from Fig. 126, where the details of the differential are shown in right-line form and where the driving gears of the large and small motors have respectively 72 and 32 teeth or a ratio of 9 to 4; these being in turn driven by other gears which have the same and equal ratio of 29 to 91 from each motor. Consequently, when the large motor is running at 400 R. P. M. and the small one at 900 R. P. M. there is no resultant motion of the differential shaft, which is the condition when the controller is in the off position.

The motor field leads are carried to the small master controller and the first movement of the controller strengthens the field of the small motor by cutting out a small section of resistance, reducing the speed of this motor slightly and causing the differential to be unbalanced and a very slow resultant motion of the differential shaft is produced. While the field of the small motor is being continually strengthened by cutting out resistance, the field of the large motor remains at its constant strength, and the small motor field is strengthened until the armature is running at about 300 R. P. M., the large one during the time the small one is changing from 900 to 300 R. P. M. running at about 400 R. P. M. At this time with the ordinary turret gearing from the main driving shaft, the turret will be turning at about 25° per minute. Further rotation of the trainer's controller adds resistance to the field of the large motor, the small one at this time remaining constant, increasing its speed until it is operating at about 800 R. P. M., when the turret is then turning at its maximum speed of 100° per minute.

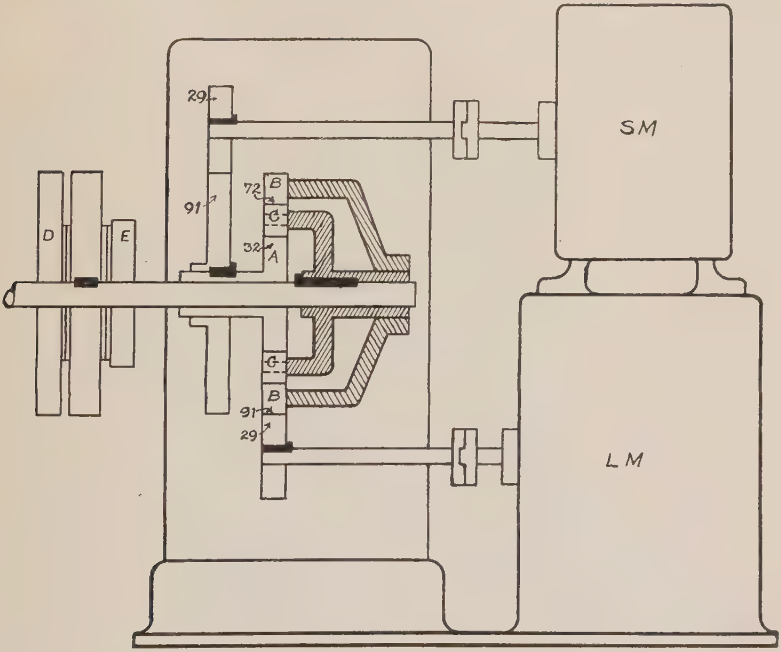


FIG. 126.—Details of Differential Gearing.

Controlling Appliances.—(Wiring diagram, Fig. 130.) The controlling appliances consist of

(1) A MASTER CONTROLLER and
(2) TWO CONTACTOR PANELS.

(1) MASTER CONTROLLER.—This controller is mounted in the turret, and is operated by the trainer. It controls the operation of the mechanism through the two contactor panels. The motor field, clutch leads, and the operating circuits for the contactor panels are led to it. None of the armature leads are taken to it. A throw-over switch previously referred to connects either contactor panel and the corresponding driving unit to the master controller.

An open view of the controller is shown in Fig. 127, showing the throw-over switch on the left at the top of controller and the controlling hand wheel at the top through the center. The speed regulation is accomplished by means of connections made on the drum cylinder and by the insertion of resistance in the shunt fields of either motor as may be required.

The small auxiliary lever, which operates the throw-over switch, is mechanically interlocked with the main operating wheel so that it is impossible to throw this lever and start the motors with the operating wheel in any but the "off" position. In case of blowing of the circuit breakers, it is simply necessary to turn the operating wheel to the "off" position and throw the starting lever to its "off" position, which resets the circuit breaker, and the equipment may then be again immediately started as before.

One revolution of the controller hand wheel gives the complete range of turret speeds from $\frac{1}{4}°$ to 100° per minute in either direction of rotation.

The throw-over switch is in principle essentially a throw-over knife switch and corresponds to a double-throw knife switch with six blades as shown in Fig. 130. Each arm of the throw-over switch corresponds to one blade and is insulated from the remaining arms.

In the central position of the throw-over switch lever both driving units are at rest, but as the lever is thrown to either side a corresponding driving unit is started and complete connections are made to the driving motors and starting panels; the other driving unit and panel being entirely inoperative.

Commutator Rheostat (Fig. 128).—This rheostat is mounted in the base of the controller.

The resistance is self-contained in separate compartments in the base of the controller, and is made readily accessible by removal of the cover around this portion of the controller. The resistance is of the unit type, and entirely enclosed, preventing the discharge of sparks in the possible event of a burn-out of the resistance. A small stationary commutator is installed in the controller for the purpose of making the various field connections to the unit resistances below. The segments on one side of the controller are cross connected to the segments on the opposite side, so that the same resistance is

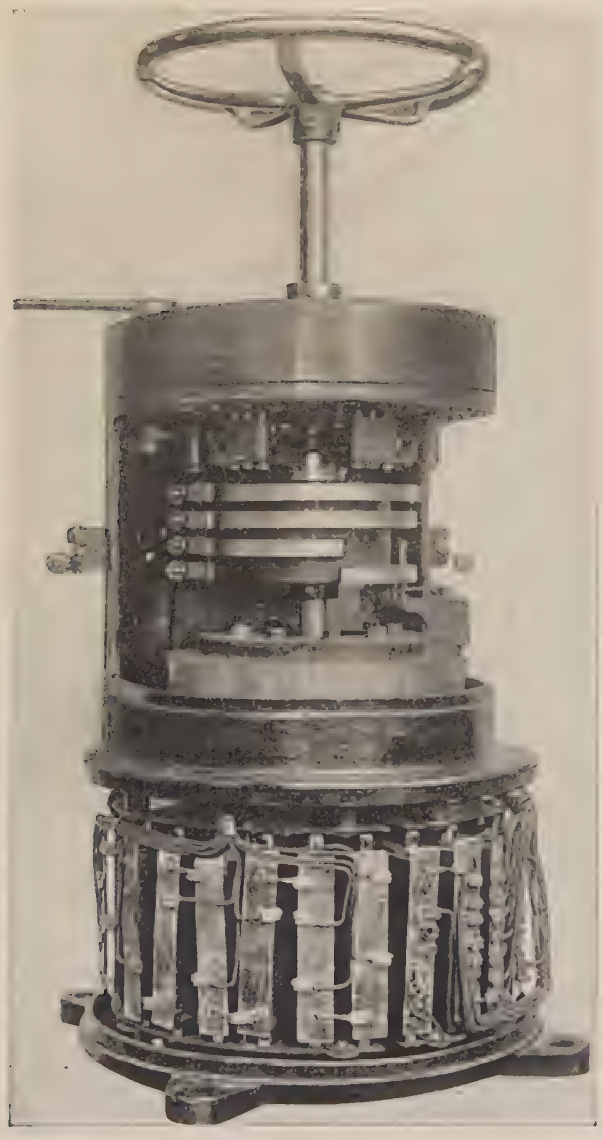


FIG. 127.—Open View of Controller.

used when operating the turret in either direction. A movable arm, carrying a small brush holder, with a carbon brush, bears on the commutator segments and is revolved by the drum cylinder. The controller is provided with a star wheel, having indents only at the "off" position and the first running position on either side. No other definite positions are provided and the carbon brush may be moved freely from the first to the last commutator segments, of which there are about 80.

Fig. 128 shows connections to field windings F and F′ of the two separate motors. One line lead is shown connected to the movable arm at its center and the arm is shown in a position called 0°, at which position the circuit to the motor field F is broken. If the arm is moved to the first segment in either direction, say to the left, circuit will be established through the arm, through all the resistance units R, then through all the resistance units R‴ and through the field winding F to the other side of the line. Tracing the connections will show that as the arm is moved more to the left, some of the resistance units R are gradually cut out, and when the arm arrives at contact 11, all of resistance R is cut out. Moving the arm still further commences to cut out the resistance unit of R‴ and this continues until the arm has been moved to contact 1, when all the resistance has been cut out of the field circuit.

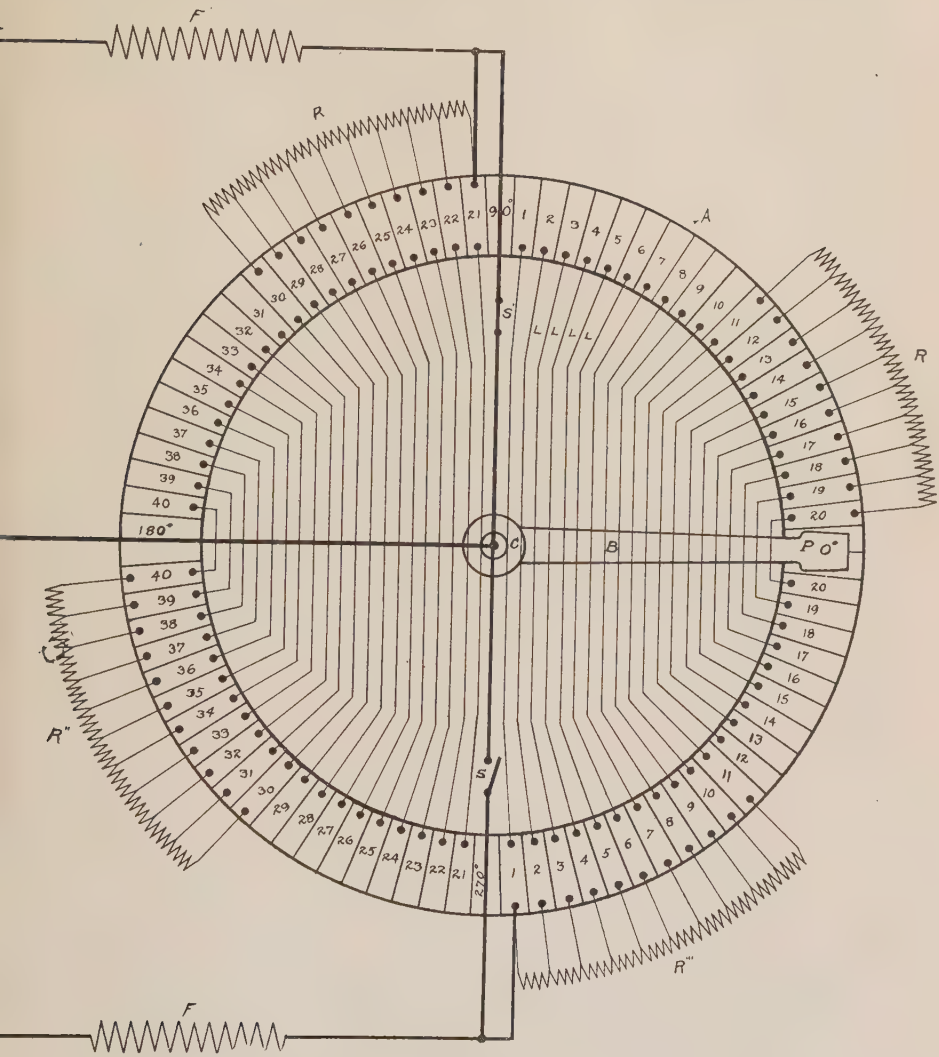
The same result would be obtained by moving the arm to the right to contact 1 and for any given position exactly the same resistance would be cut out.

If, now, when passing the dead points at 90° or 270° connection could be made by which the arm could close the switch S, it will be seen that the field of F will now remain at constant strength.

As shown, the field of F′ gets current through the switch S′, and if the arm on passing the 90° or 270° position opens this switch, it will get current through the segment 21. As the arm is now moved more to the left, the resistance units of R′ will be gradually thrown *in* the field circuit and they will all be in when the arm rests on segment 30. Continued motion will commence to throw the units of R″ in circuit and more sections will be added until segment 40 is reached. The changes in connections indicated as made by the switches S and S′ are actually made by the connections on the controller.

The same result would have been obtained, that is, the same resistance would have been thrown in the circuit of F′, if the handle had been moved to the right through the 270° position to segment 40.

This device, with the arrangement of leads given, has accomplished the following: Motor field F′ is of constant strength during the time of one-quarter revolution of the arm, and during this time the field strength of F has been gradually strengthened. During the next quarter revolution of the arm, the field of F remains constant, while that of F′ has been weakened. In other words, the motor of F has *slowed* in speed for one-quarter revolution of the arm and remains *constant* at that speed during the next quarter revolution, while the motor of F′ was at *constant* speed for the first quarter revolution and then *increased* in speed during the next quarter revolution.


F
R
90°
A
R
S′
L
L
L
L
C
B
P 0°
180°
R″
S
270°
R‴
F
1
2
3
4
5
6
7
8
9
10
11
12
13
14
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40

Fig. 128.—Commutator Form of Rheostat.

The entire reverse operation may be obtained by moving it back again in the opposite direction.

In the arrangement shown, for similar motors if all the resistance units are of equal value, the decrease in speed of F would equal the increase in speed of F′, but by suitably arranging the resistances, increasing the number for one and decreasing for the other, the relative changes of speed of F and F′ can be widely varied.

Contactor Panels or starting boxes (Fig. 129).—These panels, one for each set of driving units, are in watertight casings, and contain

Four electrically operated contactors.
Overload device.
Pilot fuses.

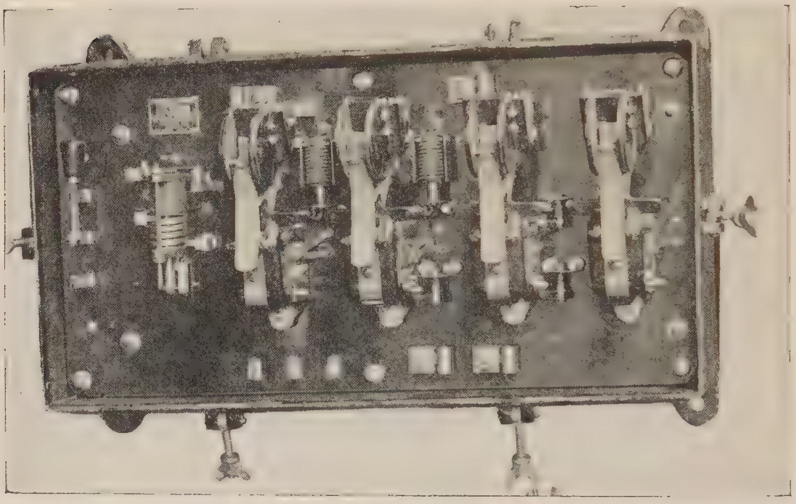


FIG. 129.—Interior of Starting Box.

A single-pole, double-throw switch, for connecting either for operation by master controller or for test.

Armature resistances (mounted on the back of the panel).

Contactors.—Number 1 (at left) and number 4 (at right) function as line switches. Numbers 2 and 3 function as accelerators to cut out the armature starting resistances. Numbers 1 and 2 are equipped with relays, called "individual series relays" which are set to drop their plungers at a predetermined amount of current.

Wiring Diagram.—A complete diagrammatic wiring diagram is shown in Fig. 130, showing the wiring of the motors, motor fields, magnetic clutch, master controller, automatic starting box and the various leads connecting them. Only one unit is shown, the other being entirely similar in its operation.

The control wires connecting a panel to the master controller are shown in a conduit and may be traced by the corresponding lettering of the wire given at the point where the wire enters and at the point where it leaves the conduit. For example, the wire at binding post E′ enters the conduit and leaves the conduit at a point in the master controller marked E′. Similarly the various connecting wires between the contact buttons on the reversing switch base and the drum fingers and wires leading to the starting panels are encased in a conduit within the master controller. These leads may also be traced by the similar lettering.

Operation:

Starting the Motors.—To start the driving unit shown, it is necessary that the hand wheel of the controller should be in the off position, after which the throw-over switch is thrown in a clockwise direction. This movement connects the middle contact of each group with the clockwise outside contact button of that group. Thus P″ is connected to PP′, CC to CC′, FF to F′, E to E′, etc. This connects the leads of the unit shown and entirely disconnects all leads to the other unit which is rendered inoperative.

The main power lines and leads to the motors, including resistances, relays, blowout coils and overload coils are shown in heavy lines, while all auxiliary starting and controlling lines are shown in light lines.

Current from the main line comes to the terminal marked + line, through the blowout coil of No. 1 clapper switch, then to and through the right-hand pilot fuse. Here the current divides; one part flows through the resistance XY, through the retaining coil of the overload magnet, through the single switch marked *normal* to the binding post PP′ through the lead to the controller to the terminal in the drum marked PP′ to the contact button PP′ of the throw-over switch, to the center contact button P″, to the terminal marked P″ in the controller drum, through the lead to the terminal P″ in the starting box, through the left-hand pilot fuse, thence to the terminal on the blowout coil of No. 4 clapper switch, to the terminal marked − line and then to the negative main lead.

This above-described circuit energizes the retaining coil of the overload magnet.

The second circuit from the lower point of the right-hand pilot fuse is led to the right-hand contact post of the auxiliary disc contact on the second clapper switch, then through the contact disc to a similar post on the third clapper switch and from this post via the disc to the upper terminal of the fourth or right-hand clapper-switch coil. This terminal is also connected to the upper terminal of the coil of No. 1 clapper switch. From these upper terminals current flows through the coils of No. 1 and No. 4 clapper switches to the common lead which connects to the overload and then follows the path described by the first circuit back to the negative lead.

These clapper-switch coils, Nos. 1 and 4, are energized by full voltage and they close immediately. The closing of these switches places the two motors in circuit with all the starting resistance. Current flows from the positive line through the blowout coil of No. 1 clapper switch, through the switch proper and then through the main overload coil. From this point the circuit divides, but as the second and third clapper switches are open, the current flows through the series relay No. 1, through all the starting resistances to the point marked No. 3, then to the terminal marked Arm, then to the common point between the two armatures where it divides through the two armatures, then from the common connecting point to the terminal marked Arm in the right-hand side of the panel, thence through No. 4 clapper switch and blowout coil to the negative line. This completes the circuit and the motors start as the fields are energized at the same time as follows:

The instant clapper No. 1 closes, current flows to binding post E′ on the panel to the binding post E′ in the controller drum and then to contact button E′ on the throw-over switch. From here current flows to the center contact button E which is connected to the drum contact finger E in the controller. Finger E is always in contact with the drum segment so that the entire drum cylinder is supplied with positive potential. The drum cylinder being in the off position as shown, finger F is in contact with the cylinder and consequently positive potential is fed through this finger to the contact button F′, then to binding post F′ in the drum and from there to the field terminal of the large motor F′. Current flows from here through the field of the large motor to the negative line through No. 4 clapper switch, and this field is energized with full potential.

The drum cylinder being of positive potential, the current, in addition to taking the circuit described above, flows to the commutator brush B′ which is mechanically and electrically connected to the drum cylinder, then through all the small motor resistance steps to finger FF in the controller, to center contact button FF on the throw-over switch, then to the contact button FF′ and then to right-hand terminal FF′ of the small motor field. Current then flows through the small motor field to the negative line through No. 4 clapper switch. This energizes the small motor field at the same time that the large motor field is energized, but it is supplied with reduced voltage while the large motor field has full potential.

ACCELERATION OF THE MOTORS.—The first rush of current through the series relay No. 1 causes it to lift immediately, raising the disc connecting the two contact posts. As the motor increases its speed, its counter electromotive force increases causing the current to decrease and when it has decreased to a certain value, predetermined by the adjustment of the relay, the disc drops and makes contact between its two contact posts. When clapper switch No. 1 closes, it makes contact with the left-hand contact post of series relay No. 1, and current now flows from clapper switch No. 1 by way of the disc to the upper terminal of the switch coil of clapper switch No. 2, by way of the upper disc of clapper switch No. 3. The lower terminal of the coil of clapper switch No. 2 is connected to the negative lead previously described, so current flows through the coil and clapper switch No. 2 closes. The closing of this switch short circuits the first section of armature resistance, that between No. 1 and No. 2, since the armature current can now pass directly from the overload coil through clapper switch No. 2 and series relay No. 2 to the point marked No. 2, instead of flowing through relay No. 1 and the first step of armature starting resistance. The cutting out of this section of the armature resistance provides the motors with a second current inrush, which speeds up the motors and lifts relay No. 2. As the accelerating current decreases again to a certain predetermined value, relay No. 2 drops and current now flows from clapper switch No. 2, by way of the relay disc to the upper terminal of the coil of clapper switch No. 3. The lower terminal of this coil is connected to the line of negative potential, so current flows through the coil and clapper switch No. 3 closes. This cuts out the remaining section of armature resistance, since the current can now flow directly from the overload coil through clapper switch No. 3 to the motor armatures. This gives the armatures another rush of current and they come up to their full speeds as determined by their shunt-field strengths.

PROTECTIVE CIRCUITS.—The closing of clapper switch No. 3 opens its upper auxiliary disc and so cuts off the positive lead from relay No. 1 to switch coil No. 2 which allows clapper switch No. 2 to open. The opening of this switch does not affect the main circuit as it is no longer carrying current and the power required to energize the coil is saved. The opening of switch No. 2 cuts off the positive lead to the third clapper-switch coil by breaking contact with the left-hand contact post of relay No. 2, but the coil of switch No. 3 still retains current through the resistance AB, since switch No. 3 is of positive potential and makes contact with the contact post B. The current in the coil of switch No. 3 is reduced by means of the resistance AB and this serves to prevent the coil from overheating.

It must be remembered that the coils of clapper switches No. 1 and No. 4 obtained their positive feed through the lower auxiliary contact discs of switches Nos. 2 and 3, consequently when No. 2 closed, this circuit was broken and it was also broken when No. 3 closed. The coils of switches Nos. 1 and 4 are energized, however, through the resistance CD, which is connected in parallel around the two auxiliary discs. This resistance reduces the current flowing through the coils of switches Nos. 1 and 4 and protects them from overheating. It will be noticed here that the motors could not have been started had either clapper switch No. 2 or No. 3 been closed for any reason when it was desired to start the motors, since switches Nos. 1 and 4 will not close on the reduced current flowing through the resistance CD. In other words, the switches will remain closed on a smaller current than that required to close them. This so-called interlocking circuit serves to protect the motors from undue current, such as would result if either switch No. 2 or No. 3 were closed previous to the line switches Nos. 1 and 4.

OVERLOAD.—In case of overload the small overload switch opens and cuts off the negative lead of all four switch coils and thus positively opens the clapper switches, which in turn opens the motor circuit. The retaining coil is still energized, though the main circuit is opened, and the overload plunger will remain in the tripped position until the retaining coil is de-energized. This is accomplished by moving the throw-over switch to the "off" position which breaks the negative lead of all the control circuits. When the retaining coil is de-energized the overload plunger drops and the overload switch is again closed. The motors may be then started by moving the throw-over switch lever to the "on" position, when the motors will start as previously described.

TESTING SWITCH.—The throw-over knife switch on the panel is used in testing out from the panel, as it carries the negative feed to the four coils and to the retaining overload coil. The motors may be stopped or the overload reset by opening this knife switch, since it interrupts the feed circuit the same as opening the connection between the contact buttons P″ and PP′ on the throw-over on the switch base in the drum controller. By throwing the knife switch to the "testing" position, circuit is established direct from the negative line to the overload switch; that is, the circuit P″, PP′ is bypassed and the motors started, irrespective of the motor controller. The shunt fields are energized even though the throw-over switch is in the "off" position, since the EF and FF circuits are closed, due to permanent connections between the outside contact buttons of each group and the adjacent buttons. EE′ and E″ are connected when the lever is in the "off" position, as also are FF′ and F″, etc.

The circuit breakers may be reset after overload by opening and again closing the knife switch, so that all the functions may be had by the knife-switch control except the speed variation and the closing of the magnetic clutch circuits.

SPEED VARIATIONS.—After having started up the motors by moving the throw-over switch to the "on" position, the hand wheel of the drum controller is moved in order to start the turret. If it is moved in such a direction as to cause the cylinder to make contact to drum contact finger CC, positive current is fed to finger CC, then to central contact button CC″ of the throw-over switch, to button CC′ and then to the terminal CC′ of the magnetic clutch coil. The common terminals of the clutch coils are connected to the negative line and the clutch CC′ is thus energized by full potential and power is transmitted to the turret. The large motor has full field strength and runs at its normal speed while the small motor has full weak field and runs at its maximum speed, and since the small motor tendency is to reverse the turret, the turret turns at a very slow speed.

As the hand wheel is turned still further, the commutator brush B moves over the commutator and gradually cuts out the small motor shunt resistance step by step. This action decreases the small motor speed by increasing the field strength, the large motor speed remaining the same, which allows the turret to turn at increasingly higher speeds. When the brush has arrived at segment No. 1 all the small motor shunt-field resistance is out of circuit and both motors are running at normal speed. Further movement of the hand wheel causes finger FF to make contact with the drum cylinder, thus feeding full potential to the small motor shunt field. At this time, drum finger F rides off the drum cylinder, and receives its positive potential from segment No. 61, or through the large motor shunt-field resistance steps Nos. 61, 62, 63, etc., as the brush rides over them and cuts resistance into the large motor shunt field. This gradually weakens the large motor shunt field and speeds up the motor, the small motor speed remaining the same, and this causes the turret to revolve still faster. This continues until all of the large motor field resistance is in circuit when the large motor will be running at its maximum speed, the small motor at its normal speed, and the turret will be turning at its maximum speed.

In order to produce a more uniformly increasing speed curve over the low-speed portion of the curve, the field resistances of the two motors in late equipments are so arranged that when resistance is cut out of one field circuit, a certain resistance is cut in the other, so the change of speed of the differential is due to the changes of speed of both the motors simultaneously.

Reversing the hand-wheel rotation reverses the cycle and the turret is turned at decreasing speeds until the "off" position of the drum cylinder is again reached, at which point the clutch coil CC′ is de-energized and the turret stops, although the motors continue running. If the hand wheel is turned still further in the same direction, finger C will make contact with the drum cylinder and feed positive potential by way of the contact buttons C and C′ through the conduit to clutch coil C′, which energizes that side of the clutch and connects power to the turret the same as before, except the train of gears has an idler inserted which reverses the direction of rotation.

It is thus seen that the turret is reversed by means of the hand wheel and that the complete range of speed variation is obtained in either direction by one turn of the hand wheel from one extreme position to the other.

It should be noted that both clutch coils are de-energized in the "off" position which has the effect of stopping the turret quickly and accurately. Permanent connections are made between the field resistances and the positive finger E, so that if for any reason the brush B was lifted from the commutator, the field circuits would not be opened.

The motors may be stopped by bringing the drum cylinder to the "off" position and then moving the throw-over switch lever to the "off" position, which movement opens the negative feed circuit P.

In order to start the other driving unit which is identical with the one described, it is only necessary to move the throw-over switch lever so as to move the throw-over switch in a counter-clockwise direction. This causes a cycle of operations identical with that previously described.

Care and Maintenance.—The differential casing should be kept approximately half full of grease for the lubrication and the cushioning of the differential gears. The several grease cups in the various bearings should be kept filled also with grease, although in most cases, one filling of the grease cups will furnish sufficient lubrication for a long period.

The clutch rings and brush holder should be examined occasionally, and the space between the clutch rings kept free from dirt, chips, etc. At long periods the carbon brushes bearing on the clutch rings will require renewal.

Occasionally the covers should be removed from the automatic starting boxes and inspection made of all contacts, especially the disc contacts, to see that they are clean and that the parts make proper contact in operation. The auxiliary contacts on the contactors require renewal at very infrequent periods.

The master controller, which is the essential feature of both driving units, should receive care and attention and the commutator especially inspected at regular intervals to see that the contact between the carbon brush and commutator bars is good and that there is no danger of grounding between commutator segments, owing to the collection of dirt, etc. Accumulation of moisture or dirt upon this commutator may cause grounding between segments and tend to eat out the insulating mica between segments. In the case of the possible burn-out of a resistance unit, the same may be removed from the controller and spare unit inserted without disturbing adjacent units. In inserting new resistance, special care should be taken to see that the proper amount of resistance is in circuit, as the proper operation of the system depends upon the required amount of resistance in circuit on a given controller position. If, for example, a unit was removed and a new resistance unit of higher ohmic value inserted in the field of the small motor, it would tend to produce too high a speed of the small motor, which would unbalance the differential in the wrong direction, and tend to make the small motor instead of the large one drive the turret; a thing to be avoided. If too much resistance is inserted in the field of the large motor, it will require the motor to drive the turret on the last controller position at a speed greater than 100° a minute and weakening its field to this point may tend to produce poor commutation.

IV. Turret Turning—Hydraulic Speed-Gear System.

In this system of turret turning, a shunt-wound, non-reversible motor runs at one speed. Its shaft connects to the A-end of an hydraulic speed gear. The speed and direction of train of the turret is controlled through the speed gear.

Hydraulic Speed Gear.—The hydraulic speed gear is a machine for transmitting rotary torque at variable speeds in either direction, without steps or abrupt graduation, while the source of power rotates continuously in one direction, without any necessary change of speed. This source may be an engine of any kind, an electric motor, a shaft, or any rotating mechanism from which it is desired to transmit power.

The variation of speed is very wide and smooth. This apparatus is seen at once to fill one of the most difficult requirements to meet in turret turning and gun elevation.

This gear or modifications of it, electrically driven, is being used on new ships for turret turning, gun elevating, turret rammers, steering gear and anchor windlass.

The gear is fully described in the text-book on "Naval Ordnance" and only the electric equipment will be described here.

Electrical Equipment.—The electrical equipment consists of a 50-horsepower, shunt-wound, totally enclosed motor, and contactor-type controlling appliances.

CONTROLLING APPLIANCES.—These are solely for starting the motor and consist for each turret of a

Contactor panel operated by a
Master switch.

On the front of the panel are mounted:

Two line contactors:
Four accelerating contactors.
One shunt contactor for cutting out the series contactor at the last point.
One overload relay.
Two fuses for the control circuit.
Single-pole, double-throw switch for local operation.

The resistance is mounted in a separate case.

A wiring diagram is shown in Fig. 131.

ACCELERATING CONTACTORS.—The accelerating contactors are of the current limit series type, without blowout. Their construction is such that when the circuit is closed these contactors will not close until current is reduced to a predetermined amount for each step, when the contactor will close, cutting out a step of the resistance.

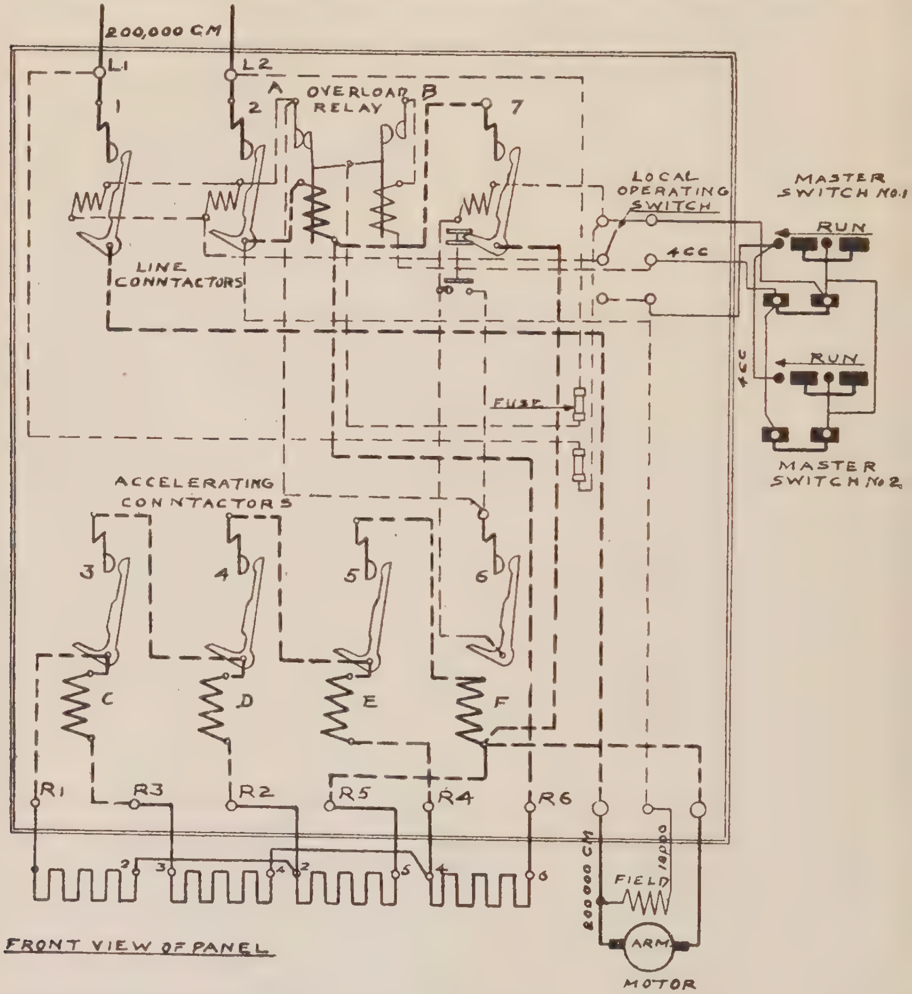

200,000 CM
L1
L2
1
2
A
OVERLOAD RELAY
B
7
LOCAL OPERATING SWITCH
MASTER SWITCH No. 1
RUN
4CC
LINE CONNTACTORS
4CC
RUN
FUSE
MASTER SWITCH No 2
ACCELERATING CONNTACTORS
3
4
5
6
C
D
E
F
R1
R3
R2
R5
R4
R6
2
3
4
2
5
4
6
200000 CM
10000
FIELD
ARM
MOTOR
FRONT VIEW OF PANEL

FIG. 131.—Hydraulic Speed-Gear System of Turret Turning. Wiring Diagram of Motor Control.

OPERATION.—The "local operating switch" is closed *down* for operation by the "master switch" (up for local operation).

The master switch is moved to "running" position to start the motor.

(1) The two line contactors will close, the armature circuit then being closed through the motor, and all the resistance, and the field energized. There is a rush of current until the motor gains speed.

(2) When the current has reduced to a predetermined amount the magnetic effect in coil C will be reduced sufficiently to allow contactor No. 3 to close cutting out resistance R1-R2.

(3) When the current is again sufficiently reduced (by the motor speeding up) in coil D, contactor No. 4 will close cutting out resistance R3-R4.

(4) When the current is sufficiently reduced in coil E contactor No. 5 will close cutting out resistance R2-R5.

(5) When the current is sufficiently reduced in coil F, contactor No. 6 will close. The operating circuit of contactor No. 7 is energized and that contactor closes, cutting out resistances R4, R6, and the motor is connected directly across the line, the series contactors 3, 4, 5 and 6 being cut out.

Overload Relay.—The overload relay consists of a magnet frame carrying two coils, one series and one shunt, one placed in front of the other. Above the coils are two arms, which are operated, one by the plunger of each magnet coil, and carrying the moving contacts that bear against the contact posts secured to the panel.

The construction of the arms are such that one set of contacts is closed at a time. It is noted that all times the current passes through the series coil of the overload relay, the normal position being with the contacts A closed. Should there be an overload on the line, the plunger of the series coil will be drawn up, which causes A to open and B to close. Contact A opens the control circuit of the line circuit which causes all contactors to open. This condition will remain until the master switch is brought to the off position when the shunt coil of the overload relay will be energized, drawing up its plunger which opens contact B and closes contact A, when the panel can again be operated and the motor started as before. Contact B is not opened until the operating levers have returned to their normal position so that the shunt coil is in circuit only momentarily.

GUN-ELEVATING SYSTEMS.

Much less power is required for the operation of turret-gun elevating equipment than for turret turning, but in other respects the conditions to be met are very similar.

The **requirements** for gun-elevating equipment are:

(1) Wide range of speed, with smooth and rapid increase or decrease and reversibility.

(2) Capable of standing continual changing of speed and reversing.

(3) The speed in any controller position must be constant.

(4) Must stop and hold the load at any point, with a minimum of drift when the controller is brought to the off position from any other position.

Several systems have been used to obtain these results. They are:

(I) Direct system.
(II) Motor-generator system.
(III) Non-reverse system.
(IV) Hydraulic speed-gear system.

(I) Direct System.

In this system the elevating motor armature was connected directly to the constant potential mains, and the speed varied by varying a resistance in series with the armature. This did not allow of very fine control, and was soon abandoned.

(II) Motor-Generator System.

This system is the Ward-Leonard system of control using a motor generator to furnish current for the elevating motor. As the Ward-Leonard system has been fully described under "Turret-Turning Equipment," no further description will be given here.

(III) Non-Reverse System.

This name has been used for a form of electric control in which the motor runs continually in one direction, reversal being arranged by a system of mechanical clutches. The equipment consists of a **shunt motor** with **drum controller** and **rheostat**. The armature control is entirely rheostatic. The controller cuts resistance in or out of the armature circuit.

(IV) Hydraulic Speed-Gear System.

This gear, operated by a motor is now generally used for gun elevating, and has been installed to replace nearly all the older types. Its wide range of speed, including extreme slow speeds, and smooth changes of speed, makes it particularly adapted for this operation.

The **motor** is shunt wound, 18 horsepower in *Nevada* class.

The **controlling appliances** consist of a watertight, non-reverse drum controller, with self-contained clapper switch and overload relay, with separately mounted resistance. The clapper switch opens the motor circuit upon failure of line current or by operation of overload relay. When the clapper switch is opened from any cause it can only be reset by bringing the controller handle to the off position. A wiring diagram is shown in Fig. 132.

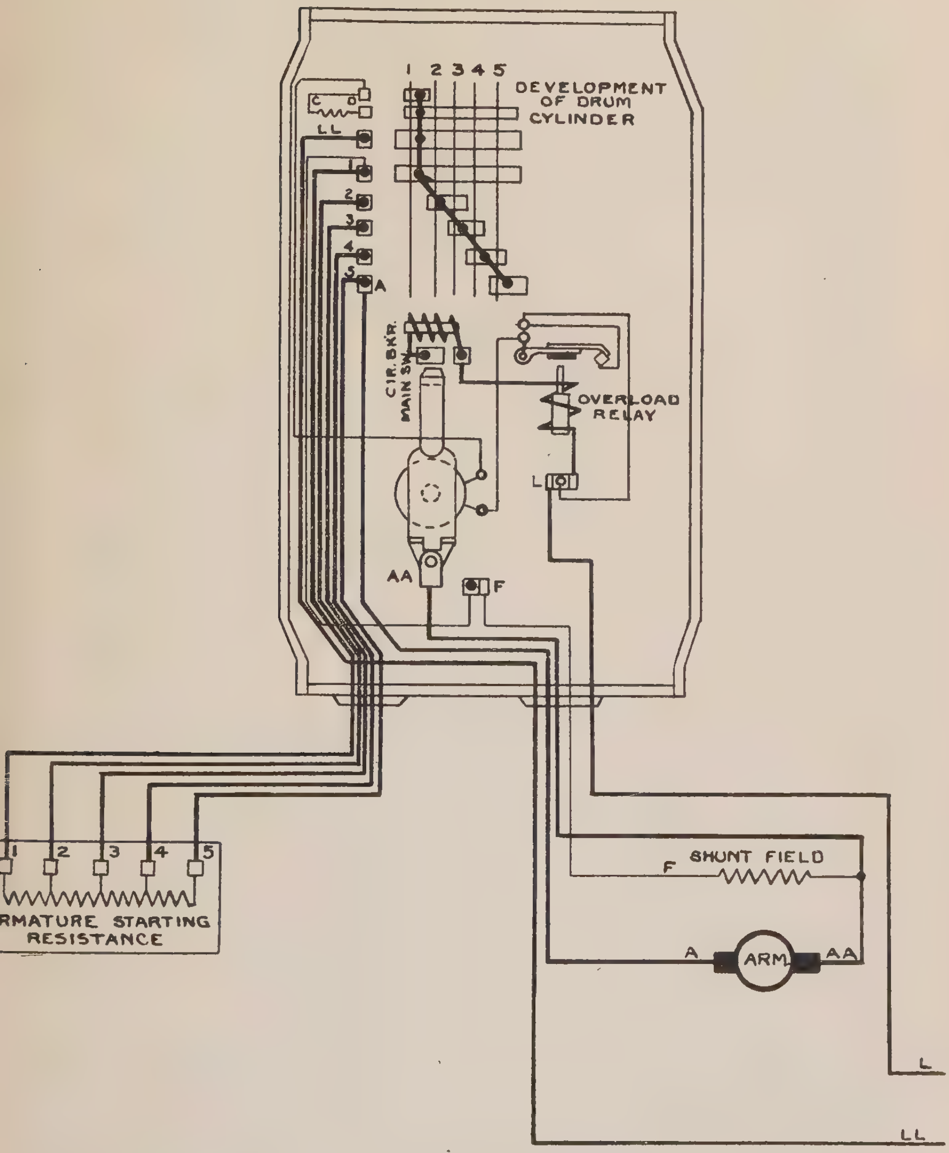

1 2 3 4 5
DEVELOPMENT OF DRUM CYLINDER
C
O
LL
1
2
3
4
5
A
CIR. BK'R.
MAIN SW.
OVERLOAD RELAY
L
AA
F
1
2
3
4
5
RMATURE STARTING RESISTANCE
SHUNT FIELD
F
A
ARM
AA
L
LL

Fig. 132.—Gun Elevating, Hydraulic Speed-Gear System. Motor Control Wiring Diagram.

TURRET-RAMMER EQUIPMENT.

A rammer for gun loading is designed with the object of loading the gun rapidly and certainly. The gun must be loaded as quickly as possible; the shell must be firmly seated, and the powder follow the shell with the least possible delay.

The rammer must accelerate rapidly, carrying the shell into the gun; the power must be applied continuously until the shell is firmly seated while the rammer slows down, and finally stops at the end of the stroke; the rammer must be withdrawn rapidly without load, and slowed and stopped without jar, then—if power loading is used for the powder—make the shorter powder stroke.

In all electrically operated turret-rammer equipment the motor shaft is connected to the rammer through a *friction safety clutch.* When the motor takes an excessive current, as when slowed down and stopped in seating the shell, the armature shaft slips in the clutch. This keeps sufficient power on the rammer to seat the shell firmly, but prevents excessive strain and damage to the rammer, and blowing of the circuit breaker.

On early types, series motors were controlled by an R drum controller. Acceleration and retardation were accomplished by the operator handling the controller.

The next developments were the use of compound motors, then contactor controllers, providing automatic acceleration and later, limit switches to automatically retard at the end of the strokes. These developments, however, introduced complicated apparatus that did not always function properly, and simpler methods of control followed. A number of installations are still retained, however, on the older ships.

The fact that, in this case, as in several others that have been noted, apparatus that was complicated by too many automatic features has been superseded by simpler designs, does not mean that the automatic features were objectionable, and will not be tried again. The desirability of the automatic features led, in each case, to numerous designs that included them. The fact that the design did not work satisfactorily does not mean that the same object cannot be obtained in some other way.

In fact with much of the apparatus that is said to be too complicated for use, careful study of the design, its adjustments, care and operation, has produced excellent results.

The next step was the use of drum controllers with six speeds each way. The acceleration and retardation again under the control of the operator, but with dynamic braking devices, so that immediate slowing down or stopping is obtained by bringing the controller from full-speed position to the second or first position, or to the "off" position. Powerful spring buffers are provided to take any jar at the end of the stroke.

In the latest ships, the hydraulic speed gear, referred to under "Turret Turning" and "Gun Elevating," is being used.

As in those equipments, a shunt motor operates the speed gear, and the speed control is obtained through the gear. All the above types of equipment will be found in use in the service.

Description of several types of rammer equipments now in use on ships in the fleet are given below to illustrate the electrical principles involved and to show how the requirements are met. They are referred to as type I, type II, etc.

Turret-Rammer Equipment—Type I.

The equipment of the battleships referred to under this heading consists of

Motor.
Drum controller with separate panel and rheostat.
Two contactors.

Motors.—The motor, manufactured by the General Electric Co., is totally enclosed, 10 horsepower series wound.

Controlling Appliances.—The controlling appliances consist of a *drum controller,* with separately mounted *panel, contactors* and *rheostat.*

Controller.—This is an R controller with four speeds forward and two reverse. (Figs. 133 and 134.) It is mounted in the turret in the rear of the gun.

Panel.—Upon the panel are mounted the overload relay, resistance unit, a double-pole, single-throw line switch and fuses.

The *overload relay* is designed to open the operating circuit of the line contactors when the current exceeds a predetermined amount and is calibrated from 125 to 250 amperes. It consists of two coils, the upper or shunt coil being connected in series with the resistance unit across the line. Below this is an overload coil in series with the line which operates upon a movable core, lifting it when the current exceeds that for which the relay is set. Attached to the lower end of the plunger are two contact discs, the upper one of which is in series with the contactor operating circuit, and is normally closed, the lower one in series with the shunt coil and resistance unit. The upper contact disc is of steel and forms a part of the magnetic blowout circuit for quickly extinguishing the arc of the contactor circuit. The circuit is led through the two "snap coils," so placed as to form a small magnetic blowout when the disc is lifted.

Contactors.—The contactors consist of a frame carrying a fixed and a movable contact and solenoid. The solenoid is of sufficient power to hold the contacts closed against severe shocks or vibration. Arc chutes and a magnetic blowout coil are also provided. Since the moving contact is connected

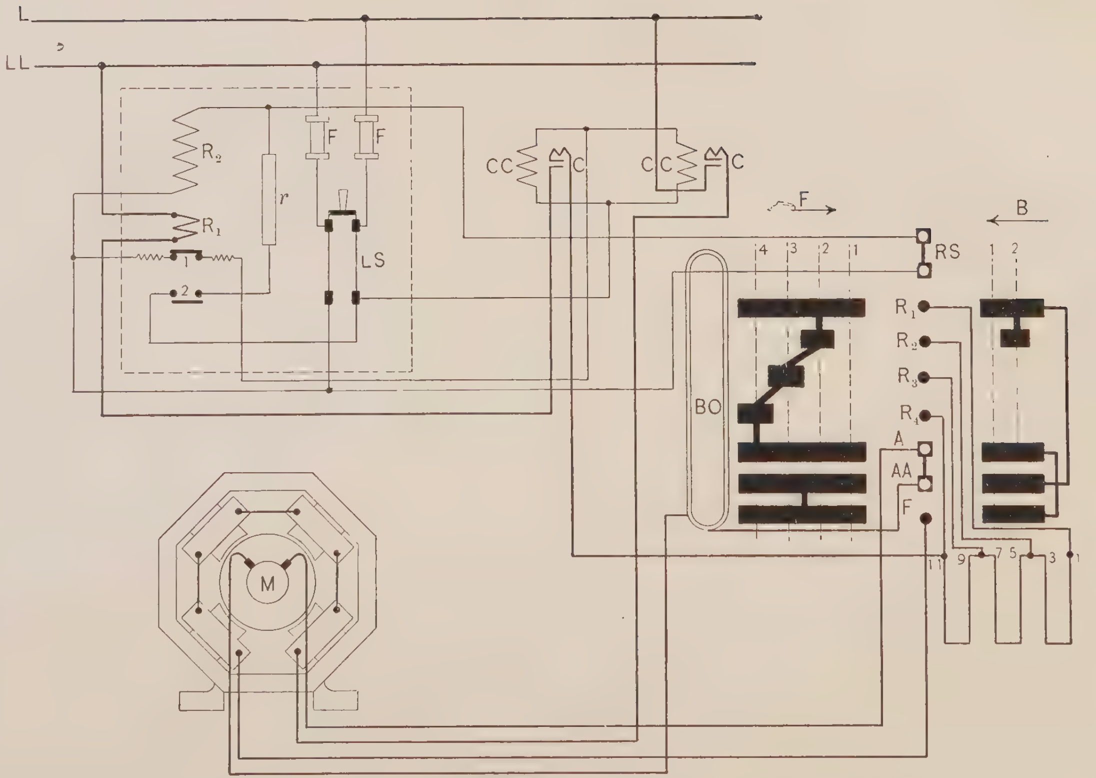

L
LL
R₂
r
F
F
R₁
1
2
LS
CC
C
CC
C
F
B
RS
4
3
2
1
1
2
BO
R₁
R₂
R₃
R₄
A
AA
F
11
9
7
5
3
1
M

FIG. 133.—Turret Rammer Equipment. Type I. Wiring Diagram.

to the frame, the whole contactor is insulated, being mounted on insulating bolts or studs.

METHOD OF OPERATION.—The motor is operated by rheostatic control and has four speeds forward and two reverse, resistance being left in circuit on the retracting stroke to prevent excessive speed of rammer.

The diagrammatic connection of the complete equipment is shown in Fig. 133 and the elementary diagram in Fig. 134, the lettering in each being the same.

The circuit is completely disconnected from line by opening the line switch LS. Closing the switch closes the line contactors and places the control of the rammer entirely with the operator. The turning of the controller short circuits the different steps of resistance. The contactors are energized all the time the line switch is closed, the winding of the coils being such as to stand full voltage continuously without injury. The armature is short circuited at the "off" position, thus providing a dynamic brake for stopping the rammer.

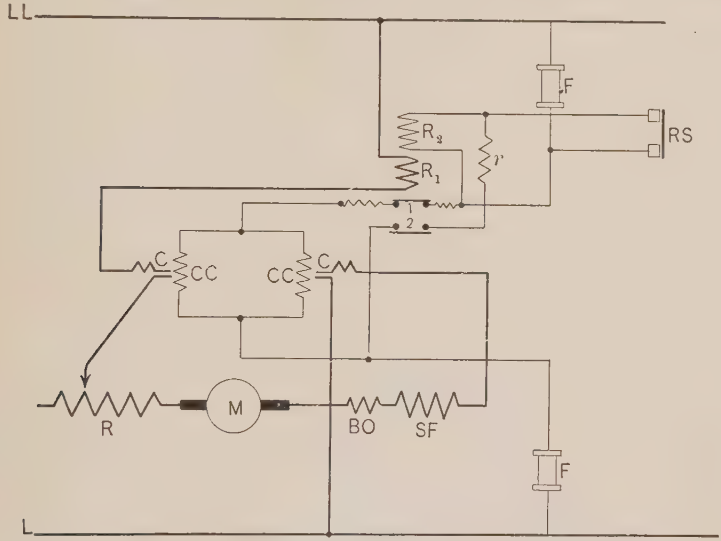


FIG. 134.—Turret Rammer Equipment. Type I. Elementary Wiring Diagram

When the line switch LS is closed, the operating circuit is completed as follows: From line LL through left-hand fuse, through switch, through disc 1, which is normally closed, through the two contactor coils CC, and thence through switch and right-hand fuse to line L.

When the contactor coils are energized, the contactors C close and the main circuit is made up to the controller. When this is moved to its first speed position for ramming, circuit is made from line LL through coil R_1, through left-hand contactor C, through resistance from 11 to 1 to finger R_1, to controller segments, to finger A, to and through armature and blowout coil to finger AA, to segments, to finger F, to and through series field, through right-hand contactor C to line L.

Moving the controller successively to the position 2, 3 and 4 cuts out the resistance 1 to 11 and at the full-speed position all resistance is out.

Reversing the controller reverses the current through the armature. In case of an overload the plunger of the overload relay is pulled up by the excess of current in the coil R_1, which is in series with the main line.

This plunger lifts both the discs 1 and 2, the lifting of 1 opening the operating circuit de-energizing the contactor coils opening the contactors and thereby the main circuit. When disc 2 is lifted, circuit is made through the line switch, disc 2 and coil R_2. Coil R_2 being energized holds up the plunger that was lifted by R_1 and the main circuit remains broken.

To make the equipment operative again, it is only necessary to move the controller to the "off" position, this operation short circuiting the coil R_2, which is thus de-energized and allows the plungers carrying the discs to drop. The dropping of disc 1 completes the operating circuit and the contactors close.

Turret-Rammer Equipment—Type II.

The rammers operated by this equipment are provided with powerful spring buffers at the limits of travel. The rammer head is provided with a powerful spiral spring which acts to reduce the shock when ramming the shell home. Acceleration and retardation are under the control of the operator. Dynamic braking is provided.

MOTORS.—The motors are cumulative compound wound of 10 horsepower, totally enclosed. (Wiring diagram, Fig. 135.)

CONTROLLING APPLIANCES.—There is a drum-type *controller* reversible, with clapper-type switch, and overload device in same casing. The *rheostat* is separately mounted.

The controller is provided with two very powerful centering springs for automatically returning the drum cylinder to the "off" position from any other position.

OPERATION.—The elementary wiring diagram is shown in Fig. 135. The drum has six speed positions for either ramming or retracting, and for any corresponding position for ramming or retracting the speed of the motor is the same.

In the **first speed** position, say for ramming, the shunt field is excited, the contactor C is closed and the motor is connected across the line in series with resistance, and in addition the armature is shunted by a low resistance.

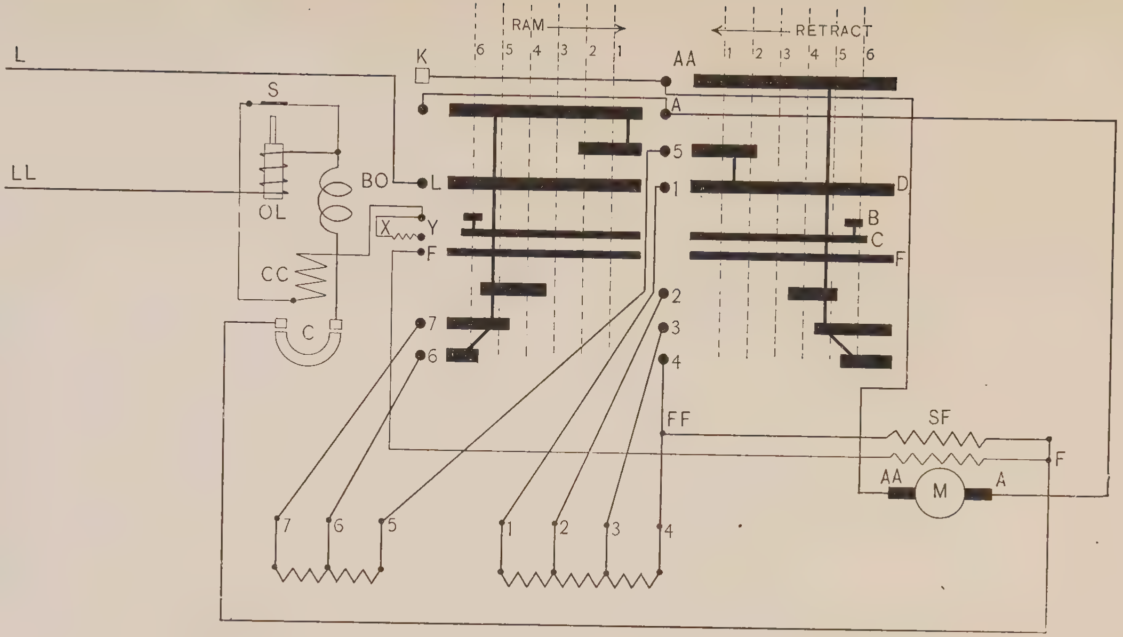

RAM
6 5 4 3 2 1
RETRACT
1 2 3 4 5 6
L
LL
K
AA
A
S
OL
BO
L
5
1
D
B
C
F
X
Y
F
CC
C
7
6
2
3
4
FF
SF
F
AA
M
A
7 6 5
1 2 3 4

FIG. 135.—Turret Rammer Equipment. Type II. Wiring Diagram.

In this position the drum is turned so that both sets of segments move to the right, so as to bring the center vertical row of fingers under the vertical line 1 under "Ram" and the left-hand vertical row of fingers under the vertical line 6 under "Retract."

Current flows from the line LL through the overload coal OL, across the switch S and through contactor coil CC to segment B, to segments C and D, to finger L and line L. This energizes the contactor coil CC, which closes contactor C. The shunt field is then energized from the main line at terminal F, current flowing through the field to finger F, to segment F, then to segment D, to line L.

When contactor C closes, the main current flows through the overload coil OL, blowout coil BO, contactor C, through the series field and through all the resistances from 4 to 1 to finger 1, through ram segments to finger A, through the armature to finger AA, to contact K, through retract segments to segment D, and then to finger L and line L. At the same time, at finger A, the current divides, the main current following the path given above, the other current flowing from finger A to finger 5 through the ram segments, through the resistance 5 to 6 and to finger AA, through the retract segments.

The result of moving the drum cylinder to the first position has been to connect the motor in series with all the resistance from 4 to 1, and at the same time to shunt the armature with a low resistance from 5 to 6. This insures a very slow speed, if in ramming the rammer chain tends to overhaul the mechanism, for the shunt resistance will act as a dynamic brake on the motor, causing the motor to act as a generator. This shunt resistance assists to keep the motor speed very low if the load is small, as well as when considerable power is required. This resistance may be adjusted so as to stall the motor at a predetermined value of armature current.

In the **second speed** position the same resistance is in series with the armature, but the shunt resistance is increased. In this position no contact is made with fingers 2, 3 and 4 to which the corresponding numbered resistances are connected, but the retract segment, which made contact with finger 6 in the first speed position, now breaks contact, introducing the extra resistance from 6 to 7 in the shunt resistance. This provides a somewhat higher speed, the functioning of the motor being otherwise the same as for the first position.

In the **third speed** position, contact with finger 7 is broken and this removes all the shunt resistance, which causes the motor to run at a higher speed.

In the **fourth speed** position, contact is made with finger 2, which has the effect of short circuiting the resistance from 2 to 1, leaving only from 4 to 2 in circuit. This increases the speed.

The next two positions cut out the resistance from 3 to 2, and from 4 to 3, and the motor runs at its highest speed.

This arrangement provides a large number of speeds and gives a flexible control. Ammunition may be rammed at a high speed until near the end of the stroke where an immediate slow down may be obtained by bringing the controller to the second or first positions; the shunt resistance acting as a dynamic brake in absorbing the energy of the inertia. Similar control is available for retracting.

In throwing the controller to the "off" position, the clapper switch C opens first, where the arc is taken and then the other side of the line is opened on the drum cylinder at the finger. The clapper switch is provided with a powerful blowout coil and renewable arc rupturing contacts, and the arc caused by breaking the circuit when moving the controller to the "off" position or in case of overload is taken by the contactor.

OVERLOAD.—The overload device carries a magnetic coil of large carrying capacity in series with the armature and operates to lift a plunger at a predetermined value of current. The lifting of this plunger opens the switch S in the circuit of the clapper switch and this opens the contactor. After an overload it is necessary to bring the controller to the first position in order to reset the circuit breaker.

There is an interlocking resistance XY, which is in the circuit of the contactor coil after the first position is passed, and owing to this resistance, the contactor coil will not be sufficiently energized to lift the contactor if it opens on overload, and the controller must be returned to the first position. This resistance is short circuited in the first position, but on succeeding positions the contactor will remain closed on a less current than it takes to close it.

Turret-Rammer Equipment—Type III.

On the *Pennsylvania* and later battleships the rammers are operated by means of an hydraulic speed gear. The gear is operated by a shunt-wound motor with controller for starting duty only similar to that described for "Gun Elevating." The control of the rammer, acceleration, retardation. etc., is in the hands of the operator through the hydraulic gear.

TURRET AMMUNITION HOISTS.

The object of this equipment is to get the ammunition from the handling rooms to the guns safely in the shortest possible time. All hoists in which one shell or one charge of powder is hoisted at a time must be started up, loaded; accelerated rapidly to full speed; retarded as it approaches the top just enough to allow it to land without jar, or in the case of tube hoists, to throw the shell clear of the tube. Then lowered, empty, at high speed, and retarded at the bottom. Provision must be made for lowering the ammunition. The latest type, described below, furnishes a continuous supply, similar to the chain ammunition hoist in principle, and the requirements differ from these.

Hoists and their electrical and mechanical equipment have undergone many changes in the last 10 years. Three types that involve the electrical principles of those now in use will be described.

Type I, Double-Stage Automatic Control.

The electrical equipment of this hoist includes automatic acceleration when the hoist is started, and automatic retardation at the ends of travel, by means of a limit switch. It also includes a provision for holding the car in the rear of the breech of the gun at any stage of elevation. These features are included in a number of single-stage, double-stage and two-stage hoists now in use on the older ships.

The hoist described below is a **double-stage hoist** manufactured by the General Electric Company.

When the controller is thrown to the full-speed position in either direction, the motor starts, is automatically accelerated to its full speed and the cars are automatically retarded and stopped at their limits of travel. When the cars have reached their limits of travel in either direction, the controller is thrown to the " off " position. For turret guns, designed to have a variable loading position, the upper car is arranged to stop at the breech of the gun at any elevation of the latter without interfering with the lower car. When the car stops at the breech of the gun, a certain " balancing " current passes through the hoisting motor armature, sufficient to keep the hoisting cable taut, while the car is controlled in its further motions by the elevating motor.

The electrical equipment consists of the **motor, brake, brake rheostat** and **controlling appliances.** The controlling appliances are of the contactor type and consist of the **master controller, limit switch,** two **contactor panels,** one **control panel** and the **wiring connections.**

Motor.—The motor is the design of the General Electric Company and is rated as CB-25, 40 horsepower, 400 R. P. M., 120 volts, shunt wound.

Brake.—This is a disc brake. The brake discs are of alternate cast iron and bronze, the former being held from rotating inside the brake frame by longitudinal keys, while the latter are held from rotating on the shaft by similar keys, this arrangement permitting the discs to be forced together by springs in the brake head, or to be released when the armature against which this spring presses is attracted by current in the brake coil.

Brake Rheostat.—In order to obtain prompt operation of the brake it is necessary that it operate with a low voltage across its coil. To obtain this a brake rheostat is inserted in series with the coil so that the voltage on the latter is approximately 45 volts with 6.2 amperes passing through the brake coil.

Controlling Appliances:

MASTER CONTROLLER.—This is a drum-type controller. It is designed with a spring to return the cylinder to the "off" position when the hand is removed. A developed view of the controller is shown in the wiring diagram, Fig. 136.

LIMIT SWITCH.—A developed view of this switch is shown in Fig. 136. It consists of a suitable frame and casing containing fingers which bear against segments on a rotating cylinder so spaced as to give the combination of control circuits necessary for starting and automatically stopping the hoist at the top and bottom. Seven of these fingers are permanently fixed and control the stopping at the bottom; the other four fingers are mounted upon a rotating yoke and control the stopping and application of balancing current at the top. The cylinder of the limit switch is turned by gearing directly from an intermediate shaft of the motor. The movable fingers are turned by gearing attached to the gun, and as the gun is elevated or depressed these fingers rotate around the limit switch cylinder. This causes the cylinder to move through a greater or less angle in order to stop the car at the top. Thus if the breech is depressed, the car does not have to be hoisted so far and the cylinder in turning, due to the hoisting motor, does not have to rotate so far before the controlling circuits for retarding and stopping are broken.

CONTACTOR PANELS.—These are enclosed in sheet steel cases, watertight and flame proof, and carry the contactors Nos. 1 to 10.

CONTACTORS.—These contactors are switches operated by magnet coils and serve to close the line to the armature circuits, to cut resistance in or out of the armature circuit and to operate a dynamic brake circuit. In general, each consists of a vertical solenoid coil with movable core, which, when the solenoid is energized, actuates a horizontal switch arm. This switch is opened by gravity when the coil is de-energized. The arc is ruptured in a strong magnetic field and the contacts are subjected to a rolling motion, which at first allows them to touch at the tips and then to make contact at the heels as the core is raised.

Associated with some of the contactors are **interlocks** for the purpose of making certain electrical interlocks between contactors. The particular functions of these will be considered later. They consist of a set of insulated discs mounted upon a horizontal square brass shaft and held in position by spiral springs. These interlocking discs make contact with square connection blocks at each end. The shaft carrying these discs is moved horizontally by a projection from the main contactor arm, and, as it is supported at the ends by short links, it receives a vertical as well as a horizontal motion when it is operated, this motion producing a wiping action to the discs when they make contact with the connection posts, clearing them of any collection of dirt or dust.

CONTROL PANEL.—This panel consists of a non-fragile base supporting a *double-pole, single-throw switch with field discharge resistance,* an *overload relay, notching relay, voltage relay* and terminal blocks for the field circuit, brake circuit and necessary connections to the controller, contactors and interlocks. It is enclosed in a sheet-steel case, with a hinged door so that the switch can be operated without removing the cover of the box.

WIRING CONNECTION.—The wiring connections are shown in Fig. 136, where may also be seen in diagrammatic form all parts of the previously mentioned electrical equipment. For such parts of the equipment that are not marked, one contactor panel contains the contactors, under the magnet coils 1, 2, 3, 4, 5, and which close the gaps between the line and armature circuits directly under them; the other contactor panel contains the contactors under magnet coils 6, 7, 8, 9, 10, and which close the gaps shown directly under them. The interlock connections for those contactors which have them are shown as horizontal discs directly over the magnet coils. The control panel contains the line leads, the double-pole switch, fuses, field discharge resistance, the terminal blocks with the various connections and the overload, notching and voltage relays. The armature resistance is shown from R_1 to R_6.

This wiring diagram also shows a simple elementary sketch of the motor circuit connections and a table showing the contactors which are closed on each step of the controller.

Motor Operation.—In all the description that follows, it must be remembered that it only relates to the operation of the motor for controlling the upper car, and that the same direction of rotation that hoists the upper car lowers the lower one and vice versa.

The controller is shown in its "off" position and the limit switch in the position when the upper car is at its lowest point. As the car is hoisted, the limit switch gradually turns and the fingers and segments will assume different relative positions, and these relative positions will best be understood by considering the vertical row of fingers to remain stationary while the contact segments move bodily to the left. As the upper car is lowered, the segments will move again to the right. For the hoisting position of the controller consider the segments to move to the left, and for lowering, to the right, but it must be recalled that the controller is at its "off" position both when the car is at its upper as well as at its lower positions.

To keep trace of the leads, all terminals or contact points that have the same letters or numbers are connected.

An inspection will show that if the switch on the control panel is open, the whole equipment is dead, as all the contactors, as well as the motor field, are fed from the terminal blocks. Closing the switch energizes the motor field.

All of the contactors, except No. 10, under one condition to be mentioned later, are fed from L_2 from the left-hand terminal block to the upper segment of the controller. The return from all contactors, except No. 5, is through the lead marked 0, which goes through the overload relay to the right-hand terminal block L. Contactor No. 5 has its own separate lead to L_1.

Armature Connections.—Current for the armature of the motor is led to one side of the line contactors, the other side being connected to the armature through the resistances. Thus, as shown, the line lead L_2 goes to one side of contactor 1, and if that contactor is closed, current flows to R_7, thence through the armature to R_5, through resistances R_5, R_4, R_3, R_2, R_1 to contactor 3 and to the other side of that contactor to L_1 and back to line lead L_1.

An inspection of the elementary motor connections will show that when contactor No. 5 is closed, the resistance R_5R_6 is closed around the armature terminals and when the motor is turning, this will produce a dynamic brake tending to stop the armature. Contactor No. 5 is always closed when the motor is at rest and at other times to be later detailed. Tracing the current from the upper segment of the controller in its "off" position will show how No. 5 is closed when the limit switch is at its bottom position. This is from segment L_2 to segment 5A on the controller to fingers 5A and 5 on limit switch, thence to coil 5 and to terminal L_1 to terminal block L_1.

Contactors 1 and 3 close the line to the armature for hoisting and 2 and 4 for lowering, and these are so interlocked that both sets of contactors cannot close at the same time and cause a short circuit. This is effected as follows: When the controller is in its first hoisting position, current flows from the upper segment to finger 1-3, then to terminal 1-3, then through magnet coils 1 and 3 in parallel, through the lower interlock on coil 4 and to the terminal 0 and thence to terminal block L_1. As soon as coil 1 is energized, it breaks the interlock connection shown over it, and thereby breaks the return lead of coils 2 and 4, so that they cannot be energized and close their contactors.

When the controller is operated for lowering, current is led from the upper controller segment to the bottom left-hand segment, to controller finger 2-4, to terminal 2-4, and then through coils 2 and 4 in parallel to the common return 0 and to the terminal block L_1. At this time, the interlock above coil 1 is closed, as that coil is not energized, allowing the return circuit of coils 2 and 4 to be completed; and coil 4 being energized, raises the disc contact in its interlock and thereby breaks the return circuit of coils 1 and 3, preventing their contactors from closing as long as contactors 2 and 4 are closed. At this time it must be remembered the limit switch is at its extreme position for hoisting and the connection of controller finger 2-4 to limit switch finger VR is broken so no current flows in that direction.

The motor circuit connection will show that when contactors 2 and 4 are closed, the current through the armature is reversed.

OPERATING OF CONTACTOR NO. 5.—The table will show that for hoisting, on the "off" position of the controller, contactor No. 5 is closed, and this is closed whenever any dynamic brake is necessary to promptly stop the armature. This contactor is operated in three ways:

a. By the master controller and limit switch of the "off" and first hoisting position as already detailed. The dynamic brake is always set when the controller is off, except when the car is at the top. At this position the segments of the limit switch have been moved to the extreme left and finger 5 of the limit switch slides off the segment, breaking the circuit from finger 5A of the controller.

b. By the master controller on the first lowering position, through finger 5. This gives a slow speed for lowering heavy loads, by leaving the controller only on the first lowering position.

c. By the limit switch through the voltage relay at points marked "braking," when the car is approaching the top or bottom of the hoist. At this time for hoisting the controller is in its fifth position and the finger 5A on the controller has slid off the segment, breaking the connection to finger 5A of the limit switch, but at the same time, the limit switch has moved to the left and the segment marked VR is energized through the lead 1-3 from the controller to finger 1-3 on the limit switch. From segment VR there is a lead through the voltage relay, which is by this time closed, as described later, to the coil No. 5.

A great deal of the satisfactory condition of the hoist depends upon the operation of contactor 5 and it should receive care to see that it is always operative.

OPERATION OF BRAKE CONTACTOR.—Contactor No. 10 operates the electrical brake and it is set in all but "off" positions of the controller, and in this position also when the car is at the top and held by the balancing current. Ordinarily its magnet coil receives current by controller finger 10 in all but "off" positions. When the car is held by the balancing current, the controller is "off," and it is necessary that the contactors 1 and 3 are closed to supply armature current and it is also necessary that the brake be set. This result is thus effected. At the balancing position, the limit switch is to the extreme left and the controller is "off." Current flows from controller finger 5A to limit-switch finger 5A, to the upper small segment on the right, then to the one under it, then to fingers 1-3 and then to coils 1-3. When coil 3 is energized, it operates its interlock over it, which closes a circuit leading directly from L_2 to coil 10.

STARTING AND ACCELERATING.—The first position for hoisting shows contactors 1, 3, 5 and 10 closed, and of these 1 and 3 close the main line to the armature and act as circuit breakers, 5 operates the dynamic brake and 10 the electrical brake. This is readily seen from the elementary diagram of the motor circuits. In the second position, 5 is opened, which removes the dynamic brake and allows a little greater speed to the armature. In the third position, in addition to the others mentioned, contactor 9 is closed. This cuts out a section of the armature resistance from R_2 to R_1 and allows greater speed. It is readily seen how No. 9 is closed in the third hoisting position by finger 9 coming in contact with the segment and feeding current direct to coil 9 and to the return lead 0 to L_1. In the fourth and fifth positions, in addition to the above, contactors 8, 7 and 6 are shown as closed. Contactor 8 cuts out resistance from R_3 to R_2, 7 from R_4 to R_3 and 6 from R_5 to R_4. These contactors close one after another, first 8, in the fourth position, then 7, then 6, in the fifth position, allowing the motor armature to accelerate and attain full speed.

Contactor 8 closes when the segment for the fourth hoisting position comes in contact with controller finger 8A, by which current is led to limit switch finger 8A to finger 8 and thence to coil 8 and then to the return lead 0 to L_1.

Contactors 7 and 8 receive their positive potential from the controller segment in the fifth position through finger NR, which directs current through the notching relay, and to the positive side of coils 7 and 6. The operation of the notching relay will be described later. When coil 8 is energized, its interlock shown above it closes the negative lead of contactor 7, and it closes, and when contactor 7 is energized, it closes the negative lead of contactor 6, and it closes.

RETARDING AND BRAKING.—In the position, shown on the limit switch marked "retard hoisting," the segments have moved that far to the left over the fingers when the car is hoisting, and at a certain predetermined point, finger 8A slides off its segment; coil 8 is deprived of its positive potential and contactor 8 opens. This throws the resistance from R_3 to R_2 in the armature circuit and the motor slows somewhat. When coil 8 is de-energized, it opens the negative lead of coil 7, which is de-energized, and it, in turn, opens the negative lead of coil 6, which is de-energized. The result of this is to throw additional resistance from R_5 to R_3 in the armature circuit and the motor slows still more.

As the limit switch is turned still more as the car hoists, the position marked "braking" is reached, and contactor 5 closes, as already explained, and a dynamic brake is applied which brings the motor to rest and the car has then reached the breech of the gun.

BALANCING POSITION.—While the car is at its limit of travel and the balancing current is flowing through the armature, the controller is thrown to the "off" position, but contactors 1, 3 and 10 remain closed, as previously explained, admitting the balancing current and holding the brake open.

The balancing current is of just sufficient strength to hold the loaded car at the breech of the gun under all conditions, and to allow the car to be forced down by the elevating motor when the gun is elevated. This balancing current is increased when it is necessary to depress the gun, and consequently to raise the car, by closing contactor 9, cutting out resistance from R_2 to R_1. This is done when the elevating handle is moved to depress the gun, an interconnecting switch on the elevating gear, shown in the figure, closing No. 9 through the limit switch when the car is at the top, but not operating No. 9 under other conditions. Limit-switch finger 9 gets current from the third segment from the bottom, which is energized from finger 10, which leads to coil 10, as it will be remembered that, in this position, coil 10 is energized from a direct lead from the switch terminal and through the interlock of No. 3.

Interconnecting Switch.—This switch mentioned above consists of a brass box containing two contact fingers connected by a copper plate on a movable arm. This arm is moved by a shaft carrying an arm on the outside of the box, which is in contact with a segment operated by a rack on the variable speed gear used for elevating power. This switch should always be open when the gun is at rest or being elevated and closed when the gun is being depressed. It is closed by the segment moving out of contact with the arm, which occurs when the elevating gear is running so as to produce depression. If contactor 9 is closed, heavy balancing current will pass through the armature and the resistances will be unnecessarily heated.

Overload Relay.—The overload relay is indicated by name in the diagram of wiring connections. All of the return leads from the magnet coils of the contactors, except No. 5, pass through this relay, as shown in the upper disc and when this disc is raised the circuit is broken and all of them are deenergized and all these contactors open. Above the disc is shown a coil, which is in series with the main armature line, and when the current in this exceeds a pre-determined amount this coil operates a plunger which opens the return lead and the contactors open. This upper disc is made of steel so that it will be magnetically held under ordinary conditions and blowout coils are provided to rupture the arc at this point.

HOLDING COIL.—Above the series coil is shown a coil in series with a resistance, which is closed directly across the line from the terminal blocks L_1, L_2, by the lower disc when the relay operates, as the operation of raising the upper disc also raises the lower one. This coil serves to hold the relay open until it is desired to start the equipment again, which is done by throwing the controller to the " off " position. Doing this short circuits the holding coil through the finger R on the controller, as positive potential is now fed directly from the L_2 lead to the controller through R, back through the resistance to L_1. When this is done, the discs fall, closing the magnet coils of the contactors and opening the holding-coil circuit, and placing the equipment in a condition to be operated again.

Notching Relay.—The notching relay is indicated by name in the diagram of wiring connections. It is for the purpose of retarding the closing of contactors Nos. 7 and 6, after No. 8 has been closed, until the motor has attained such a speed as to reduce the accelerating current to a proper amount. It consists of a coil in series with the armature current line and a coil shown above it, which has its circuit completed through the lowest interlock on contactor No. 8 when the latter is connected to circuit through the controller. This coil is energized for an instant after No. 8 is closed.

Both the series coil and the other act to raise the disc shown below them and thus to break the positive potential to coils 7 and 6, but the magnetic flux is so proportioned that neither of them alone will lift the core, but if the core has been raised by the combined action of the two coils, it will be held up by the series coil until the accelerating current has dropped to a certain amount when the relay will drop and Nos. 7 and 6 will operate.

The two coils act together at the instant after No. 8 closes and the interlock of the notching relay is held up, but the interlock on No. 8 almost immediately breaks the circuit of the second coil and thereafter the current in the series coil regulates the time of allowing the positive side of coils 7 and 6 to be connected.

The current at which the series coil will allow the core to drop and connect 7 and 6 depends upon the length of air gap. If this is too small, the series coil alone may raise the core when 7 and 6 close. This would then open 7 and 6, which, by throwing in the resistance, would reduce the armature current and drop the core, and 7 and 6 would close again. This might repeat itself indefinitely, but is corrected by a proper air-gap length for a certain determined current.

Voltage Relay.—The voltage relay is indicated by name in the figure showing the wiring connections. It consists of a coil in series with a resistance which is connected as a shunt around the armature terminals of the motor and is shown as connected to the points R_5 and R_7. The coil is fitted

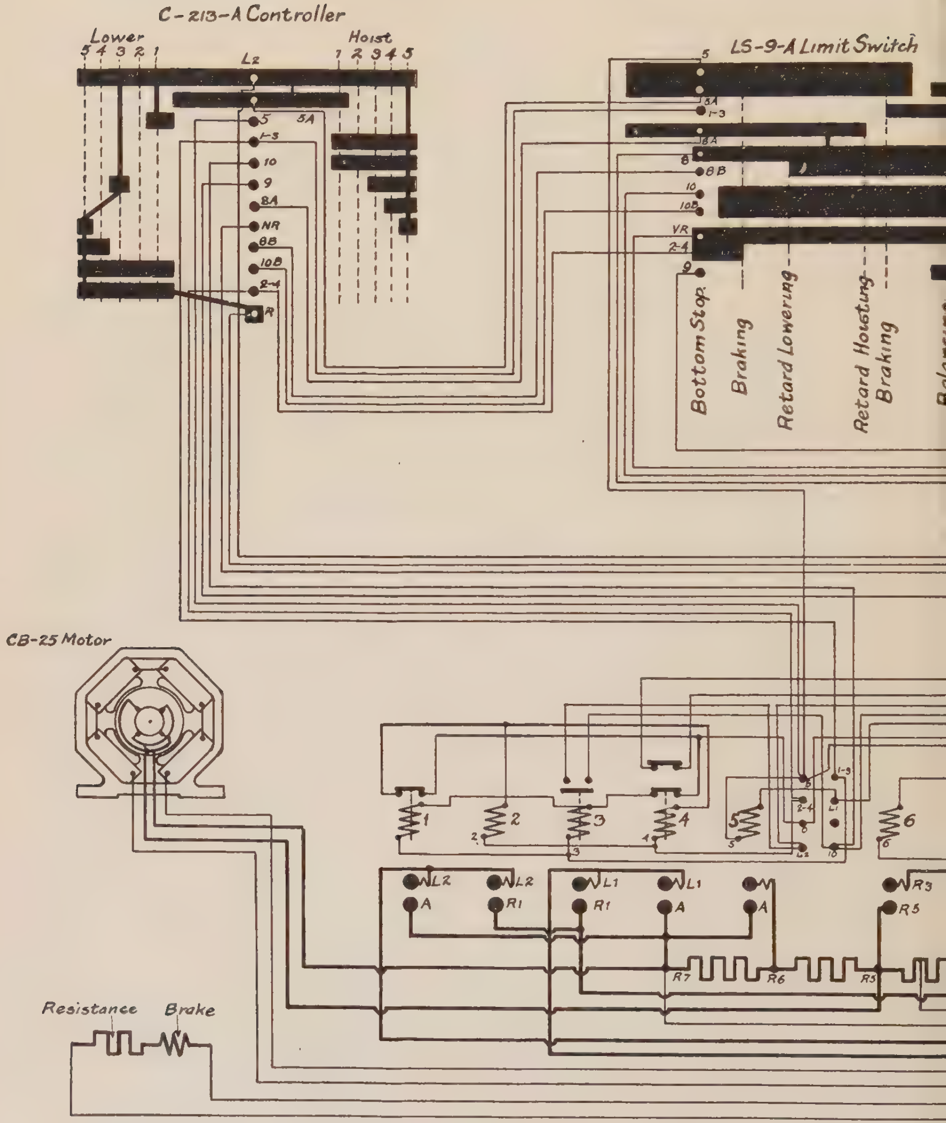
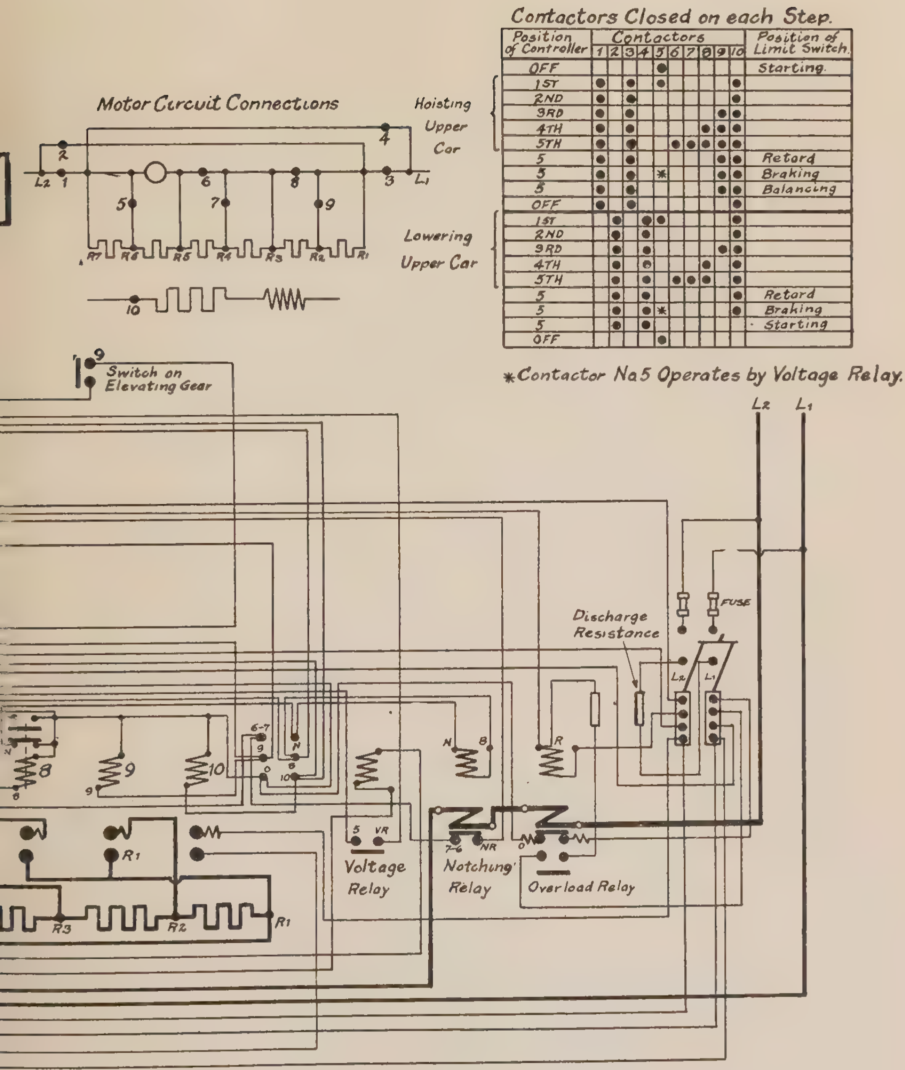

C-213-A Controller
Lower
5 4 3 2 1
L2
Hoist
1 2 3 4 5
5
5A
1-3
10
9
8A
NR
8B
10B
2-4
R
LS-9-A Limit Switch
5
5A
1-3
8A
8
8B
10
10B
VR
2-4
9
Bottom Stop
Braking
Retard Lowering
Retard Hoisting Braking
CB-25 Motor
1
2
3
4
5
6
L2
A
R1
L1
R3
R5
R7
R6
Resistance
Brake

FIG. 136.—12-Inch Ammunition


Motor Circuit Connections
L2
1
2
4
3
L1
5
6
7
8
9
R7
R6
R5
R4
R3
R2
R1
10
Switch on Elevating Gear
9
8
9
10
6-7
N
B
R
Discharge Resistance
FUSE
L2
L1
5
VR
Voltage Relay
7-6
NR
Notching Relay
O
Overload Relay
R1
R3
R2
R1

Contactors Closed on each Step.

	Position of Controller	Contactors 1	2	3	4	5	6	7	8	9	10	Position of Limit Switch.
	OFF					●						Starting.
Hoisting Upper Car	1ST	●		●		●					●	
	2ND	●		●							●	
	3RD	●		●						●	●	
	4TH	●		●					●	●	●	
	5TH	●		●			●	●	●	●	●	
	5	●		●						●	●	Retard
	5	●		●		*				●	●	Braking
	5	●		●						●	●	Balancing
	OFF	●		●							●	
Lowering Upper Car	1ST		●		●	●					●	
	2ND		●		●						●	
	3RD		●		●					●	●	
	4TH		●		●				●		●	
	5TH		●		●		●	●	●		●	
	5		●		●						●	Retard
	5		●		●	*					●	Braking
	5		●		●							Starting
	OFF					●						

*Contactor No. 5 Operates by Voltage Relay.

L2 L1

Type I. Wiring Diagram.

with a core which is connected to the disc shown below the points 5 and VR of the relay and which, when drawn up by the core, closes the circuit between those points. The coil is so wound that when the voltage at its terminals is about 50 volts, the core will be raised and will be released when the voltage drops to approximately 25 volts.

Contactor No. 5 is operated by the voltage relay, as previously described under operation of contactor No. 5. Its closing serves to cause the dynamic brake to be in operation when the car is approaching its limit in either direction. The relay core will be held up at all times when the armature voltage is above 50 volts, but contactor will not be closed until the limit switch has reached the positions marked "braking" in either direction. As the car is retarded, owing to the dynamic brake, and resistance has been cut into the armature circuit, the voltage across the armature terminals falls and the air gap is so proportioned that the dynamic brake is released about $\frac{3}{5}$ of a second before the car reaches its limit of travel.

As this relay acts by voltage, it acts to slow the armature irrespective of the load in the car and acts to bring the car to the same speed under all conditions before it opens the circuit controlling the dynamic brake. The difference in speed at which a light or loaded car will reach its stopping position depends upon the acceleration given to the loads by the same current in $\frac{3}{5}$ of a second.

It is clearly seen that to properly retard the car contactor No. 5 must close at the right instant and special attention should be paid to the condition of the disc and contacts both in the relay and in the limit switch. The resistance in series with the coil is held in clips behind the panel and its contacts should always be kept bright and clean and the tube containing the resistance should never be removed while the hoist is in use, and should always be firmly held in its clips.

Instructions for Operating.—The hoist is designed to meet the condition of operating both cars light or with a load in either car. Under these conditions it is simply necessary to throw the controller handle to full speed, up or down, and holding it there until the car is stopped at the limit. The movement of the handle can be made promptly in one motion and there is no necessity for stopping at the various notches. The handle should be held at full lower position for an instant after the upper car has reached the bottom in order to make sure that the lower car has reached the top and that the brake has set to hold it there.

In operating the hoist under conditions which are not normal, such as lowering a load in either the upper or lower car, it is not desirable to do it at full speed. Thus a loaded upper car, in lowering at full speed, would strike the bottom at considerably higher speed than a light one, and under such conditions, it is recommended that the controller be not thrown further than the third notch and the car retarded by hand when its nears the bottom.

With the upper car light and lower car loaded, the lower car should be lowered with great care, as the upper car is not electrically retarded until the lower car is landed, unless perhaps the gun is at maximum elevation, and the lower car would strike its buffers with unnecessary speed. Under these conditions, it is recommended not to throw the controller handle beyond the third notch and to retard it by the controller before the lower car lands.

It is desirable that the balancing current should not be held on when the upper car is at the breech longer than is absolutely necessary, to avoid undue heating of the resistances. The car can be held by the mechanical brake if it is desired to hold the car longer than a minute. This can be done by opening the operating switch, which, at the same time, opens the main and brake contactors and also the armature current. An appreciable time is required for the brake to set after this switch is opened, during which time the car might drop an inch or two. If it is desired to hold the car at the breech of the gun without moving, the brake circuit should be opened, giving the brake time to set, before the operating switch is opened.

Type II, Two-Stage Shell-Hoist, Hand Control.

In this equipment, the automatic acceleration and retardation are not included, and the shell is landed on the loading platform, through a tube hoist. The controlling appliances are furnished by the Cutler-Hammer Co. This type is installed on a number of late battleships. The equipment consists of a **compound motor, drum controller** and separate **rheostat.** One motor actuates both stages of the hoist, there being an intermediate point where the shell is transferred from the lower to the upper hoist. The mechanical details are such that by an arrangement of clutches, the one motor hoists and lowers the cars, while the motor is running in but one direction and no provision is made for reversal.

The electric-controlling appliances are the same as illustrated in Fig. 132 for gun elevating.

Type III, Hydraulic Speed-Gear Shell Hoist.

This is a single-stage tube hoist through which shell are hoisted by an hydraulic cylinder. One motor operates the two shell hoists by driving continuously the A-end of an hydraulic speed gear, which operates the hydraulic cylinder with a stroke slightly in excess of the length of the shell. The hoist is filled with shell for its entire length. By a stroke of the cylinder all the shell are raised, the top one being tilted at the top of the hoist so as to slide out on the loading floor flush with the rammer.

The motor is shunt wound with control for starting only. The control is similar to that illustrated in Fig. 132.

TURRET POWDER HOISTS.

On the latest battleships, and those now building separate power hoists are installed for handling the powder for turret guns. Two electrically operated types are in use.

Type 1.—This type consists of an endless-chain conveyor, similar to the 5″ ammunition hoist, single stage operated by a 7½-horsepower compound-wound motor. The motor is controlled by a drum controller, using Day control.

Type 2.—This type is a two-stage hoist. The first stage is an endless-chain conveyor, similar to that described under **type 1**. The second stage is operated by the A-end of a hydraulic speed gear. A continuous running shunt motor operates the speed gear.

CHAPTER VIII.

APPLICATIONS OF MOTORS (Continued).

CAPSTAN.

An electrically operated capstan has been installed on the after part of the main deck on the *New York* and is to be a part of the equipment of all later vessels. It is used for warping purposes and for handling a stern anchor. The requirements are similar to those for a deck winch:

1. Start with full load.
2. Withstand large and sudden increase of load without blowing the circuit breaker, as when taking in the slack of a line and a sudden heavy strain comes on it.
3. Withstand sudden decrease of load without racing, as when a line is thrown off.
4. Stand frequent changes of speed, starting and stopping.
5. Hold load if current fails.
6. Reversibility.

The capstan consists of a single gypsy head above the main deck on a vertical shaft extending to the capstan room on the second protective deck. In the capstan room are located the motor, gearing, control panels and rheostats. Mechanical gearing provides for two speeds. On the latest ships, at the low speed, the capstan is capable of hoisting 20,000 pounds at 50 feet per minute, and at the high speed is capable of hoisting 5000 pounds at 200 feet per minute.

The following description refers to the installation on a recent battleship:

The **electrical equipment** consists of one motor and controlling appliances.

Motor.—The motor is of the open type, cumulative compound wound, interpole, with an electric disc brake. On the latest ships the motor is of 45 horsepower.

Controlling Appliances.—The controlling appliances, contactor type, consist of:

A drum-type master controller.
A main contactor panel, and
A rheostat.

MASTER CONTROLLER.—The master controller is of the watertight, flameproof, drum type. Reversal of the motor and speed control are obtained by a simple lever, this lever being thrown in one direction for " forward " rotation of the motor and in the opposite direction for reversal. There are five points of speed control in each direction. The usual star-wheel device and indicating plate are provided.

MAIN CONTACTOR PANEL.—The main contactor panel consists of an impregnated asbestos lumber panel upon the front of which are mounted the electrically operated contactors, clapper switches, relays and overload device. In addition there is a double-pole main-line switch and two 4-pole, double-throw transfer switches and the necessary terminals for connection of field, brake and pilot leads. All heavy wiring connects directly to terminals on the back of the panel. The panel is supported by an angle-iron frame. The front is completely enclosed by a sheet-iron case made removable from the front for purposes of inspection and repair.

There are five contactors, shown in Figs. 137 and 138, two of which (F1 and F2) are for the "forward" operation of the capstan while B1 and B2 are for the "backward." The other contactor (R4) is used to bridge all resistance and brings the motor up to full speed. There are five clapper switches, as follows: SS (slow speed), DB (dynamic brake), BK (brake), and R2 and R3 for cutting out resistance.

In addition there are four series (controlling) relays, three of which, styled as accelerating relays, are used for controlling the sequence of operation of accelerating switches R2, R3 and R4. The fourth, styled as load relay, acts in conjunction with the overload relay, located at the top of the panel, to open the accelerating switches, as further described under "Operation." The overload relay consists of a movable core actuated by a shunt and series coil. The core serves to open contacts in the circuit of the accelerating switches. The normal position of the core is up with the contacts closed.

RHEOSTAT.—The rheostat consists of cast-iron grids mounted in three separate supporting frames. The resistance is provided with lugs for connection of the leads. Provision is made to protect these grids from corrosion.

Operation.—Moving the controller lever to the first position in one direction closes the "forward" contactors. Moving the controller lever to the first position in the reverse direction closes the "reverse" contactors, these in turn open the dynamic brake switch giving a slow speed by means of an armature shunt and close the brake relay releasing the brake. The second position opens the armature shunt clapper switch SS giving a higher speed. The next three positions close R2, R3 and R4 and cut out resistance.

The load relay operates to open the accelerating switches and insert resistance back in the motor circuit if the current rises above a predetermined value. As soon as the load current is reduced to the normal running value the load relay drops and allows the accelerating switches to bring the motor up to the full speed in the proper sequence, provided the master lever is in the full-speed position. The maximum inrush of current to the motor is controlled by means of series relays.

With master controller in "off" position switches SS and DB will remain closed. These switches control resistance steps Nos. 5 and 6 and the dynamic brake circuit to aid in stopping the motor upon return to the "off" position from any running position.

Moving master controller to first forward position picks up switches F1, F2 and BK and drops out switch DB. This places resistance step No. 1 in series with the armature and step No. 5 in shunt with the armature. This gives a slow speed of the armature, and should the load overhaul the armature would exert a braking action which would keep the speed down. A heavy load would stall.

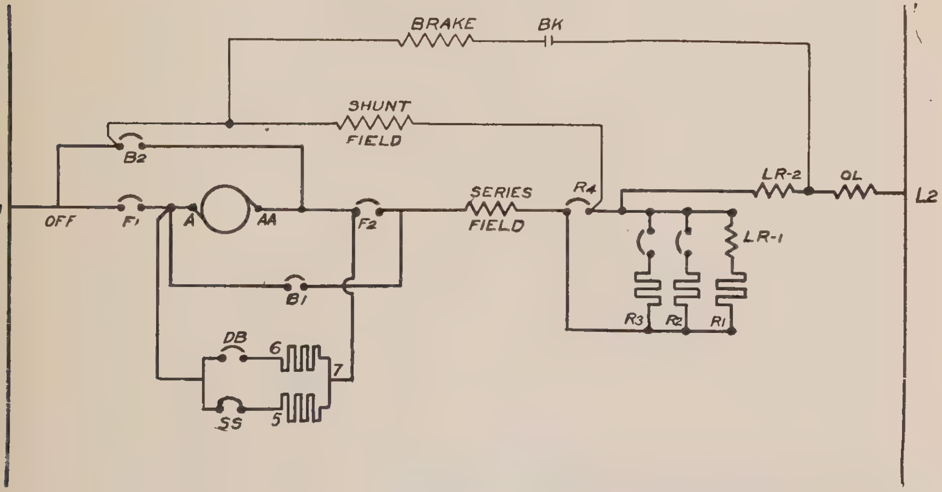


FIG. 137.—Capstan Motor Circuits, "Off" Position. Elementary Wiring Diagram.

Advancing the master controller to the second position opens SS, leaving motor armature in series with the starting resistance.

Advancing the master to steps 3, 4 and 5, respectively, reduces the resistance by closing switches R2, R3 and R4 through their series relays. Switch R4 throws the motor across the line. Moving the master controller to the first reverse position picks up switches B1, B2 and BK and drops out switch DB. All operations in the reverse direction are the same as in the forward direction above. In case the load would require more than normal current on steps Nos. 3, 4 or 5, the relay at that point would not drop and the motor could not be heavily overloaded.

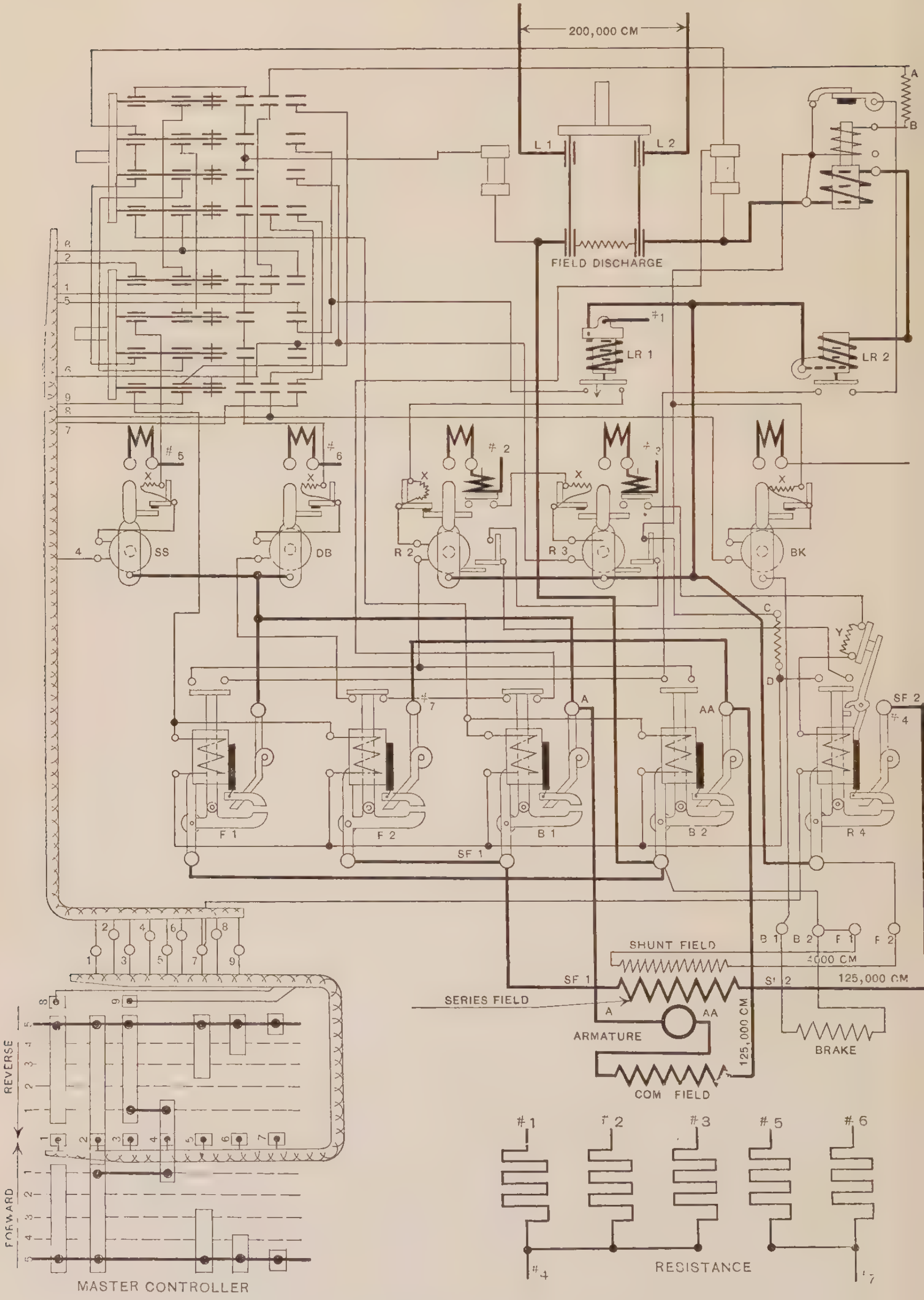

200,000 CM
A
B
L 1
L 2
FIELD DISCHARGE
#1
LR 1
LR 2
8
2
1
5
6
9
8
7
#5
#6
#2
#3
X
4
SS
DB
R 2
R 3
BK
C
D
Y
#7
A
AA
SF 2
#4
F 1
F 2
B 1
B 2
R 4
SF 1
2
4
6
8
1
3
5
7
9
B 1
B 2
F 1
F 2
SHUNT FIELD
4000 CM
125,000 CM
SF 1
SF 2
SERIES FIELD
A
AA
ARMATURE
125,000 CM
BRAKE
COM FIELD
REVERSE
FORWARD
#1
#2
#3
#5
#6
#4
RESISTANCE
#7
MASTER CONTROLLER

FIG. 138.—Capstan. Wiring Diagram.

On any controller point should the load be suddenly increased to about 175 per cent of normal the load relay would lift and insert the starting resistance by opening switches R2, R3 and R4. The load relay would then drop and the motor would automatically come up to a speed giving a safe current for the motor.

Should an overload on the motor reach the value at which the overload is set it would cut in the armature resistance as above. The motor would not speed up again until the master controller was brought to the " off " position which resets the overload.

Throwing the upper switch to the right or local control position brings the motor up to the full speed the same as throwing the master controller to the fifth position in forward direction. Throwing the lower switch to the right or local control position brings the motor up to full speed in the reverse direction.

Operation of these switches takes the control away from the master controller. When one switch is thrown to the right, opening or throwing the second to the right stops the motor.

ANCHOR WINDLASS.

An electrically operated anchor windlass is installed on the *New York* and later battleships.

The equipment for driving an anchor windlass must meet the following requirements:

1. Be capable of starting with full load.
2. To stand sudden large changes of load.
3. To retain full torque when slowed or stopped by sudden increases of load, as when breaking out the anchor, but the torque must not exceed the safe working strain on the chain.
4. Provide for variations of speed, reversing, frequent starting and stopping.
5. To hold load if current fails.
6. The motor winding and system of control must be such that, if so arranged that the load tends to overhaul the motor, no dangerous speeds will result and the load will be under control, and properly divided when motors are operated in parallel.
7. Independent operation of wildcats in same or opposite directions.

There are two methods of meeting the requirements for anchor windlasses now in use or being installed on ships under construction:

I. Contactor-Rheostatic system.
II. Ward-Leonard system.

In both of these the windlass is mounted on the forecastle and the electrical apparatus in the windlass room below the deck, except that one master controller is mounted on deck near each windlass.

The windlass is operated by means of two motors of 150 horsepower, on the latest ships. The motors are located one on each side of the windlass room, and are direct connected by a horizontal shaft. The vertical shafts that operate the wildcats are driven from this shaft by means of a worm and worm wheel at each vertical shaft. The wildcats are connected to the vertical shafts by clutches, and friction brakes are provided so that the wildcat may be disconnected and anchor let go, or veered, and held by the friction brakes. Midway between the worms on the shaft a clutch is provided.

I. Anchor Windlass, Contactor-Rheostatic System.

The electrical equipment consists of two watertight master controllers on the forecastle, and the following located in the windlass room: One non-watertight master controller, two main contactor panels, one transfer-switch panel, two windlass motors.

Principles of Operation.—By means of the clutch on the shaft and the connections provided, the following combinations are possible:

(a) WITH THE CLUTCH IN:

(1) Both chains may be hauled in with motors operating in parallel.

(2) Both chains may be hauled in at slow speed with motors operating in series.

(3) Starboard anchor may be handled by port motor, by throwing out clutch on vertical shaft under port wildcat.

(4) Same as (3) for starboard motor handling port anchor.

(5) In same way both motors may be used under combinations (1) or (2) to handle one anchor.

(b) WITH THE CLUTCH OUT:

(1) Either wildcat may be used with the motor pertaining to it.

The contactors are so arranged that, if a temporary obstruction is met with during hoisting on any notch, the safety device will not cut off current and leave the operator without control of the anchor, but will cut resistance into circuit reducing the current to a safe value, at the same time maintaining a reasonable strain on the chain. As soon as the obstruction is removed, the motor will automatically speed up to the speed indicated by the position of the master controller. This is intended to provide against jamming the anchor in the hawse pipe, or placing undue strain on the chain in case the anchor fouls some obstruction on the bottom. It is accomplished as follows:

Each controller is provided with six control speeds. The first point on the master admits less than normal current through the resistance. The second and succeeding points admit a starting inrush above normal which inrush will be controlled by individual series relays which prevent the motor from taking more than a predetermined amount of current. Should an overload be thrown on the motor, an overload relay is provided which will function to insert the starting resistances in series with the motor and reduce the current to normal. Upon removal of the overload the motor will be brought up to the speed corresponding with the position of the master.

In letting go the anchor, provision is made for allowing the chain to run out at a uniform speed under control. The rate of speed is controlled by the master controller.

The windlass is brought promptly to rest under the will of the operator by turning the master controller to the off position, which applies the dynamic brake and also the magnetic disc brake attached to the armature shaft. The control will permit the small accurate movements required to house the anchor in hawse pipe.

Motors.—The two motors are made by the Diehl Manufacturing Company, 150 horsepower, compound wound, with interpoles, reversible.

Brakes.—The brakes are of the electric disc type.

Controlling Appliances.—The controlling appliances, as stated above, consist of:

(1) Three master controllers, two on the forecastle and one in the windlass room.

(2) Two main contactor panels, one for each motor.

(3) One transfer-switch panel.

(1) MASTER CONTROLLERS.—The master controllers are of the drum type, and carry only the current to operate the solenoid switches. Each provides for six speeds hoisting and six speeds lowering. The two on the forecastle are watertight and the one in the windlass room is non-watertight.

(2) CONTACTOR PANELS.—The main contactor panels are duplicates. Each consists of an impregnated asbestos lumber panel on the front of which are mounted the contactors, relays, load relays and terminals for distant control wiring. They are supported by an iron switchboard frame. The fronts are enclosed by sheet-iron covers. On the elementary wiring diagram (Fig. 139), lower half, the contactors, H1 and H2 are for hoisting, L1 and L2 for lowering. These four serve as main line and also as reversing switches. Contactor D1 controls the closing of the dynamic brake circuit. The remaining five contactors, R1 to R5, are used as accelerating switches. They function to cut resistance out of the armature circuit with consequent increase of speed of the motor. There are five series relays whose function is

to control the time and sequence of closing of contactors R1 to R5. The "brake relay" (not shown) operates to open or close the circuit of the shunt brake. The "load relay" operates to insert the starting resistance back into the motor circuit in case of overload and thus reduce the current to normal. Upon removal of the overload the relay automatically brings the motor up to a speed corresponding to the position of the master controller. The load relays are set to lift at 2000 amperes and drop at 1050 amperes and are adjustable.

(3) TRANSFER-SWITCH PANEL.—The transfer-switch panel consists of an impregnated asbestos lumber panel on the front of which is mounted the series parallel switches, transfer switches and terminals for distant control wiring.

Operation.—With the three-pole switches thrown to the left, the motors may be operated independently from two separate master controllers, or in parallel, if the operating circuits are connected in parallel and led to one master controller. Either arrangement may be made by the switches on the transfer-switch panel. If the three-pole switches are thrown to the right, with the operating circuits connected in parallel, the two motors may be operated in series. Consider the three-pole switches thrown to the left and the central circuits in parallel, the two motors operating in parallel. In the "off" position the contactors D1 and D2 are closed, and both shunt brake coils de-energized—the brakes holding. In the *first position* in "hoist" direction the contactors H1, H2, H3 and H4 are energized, the brake coils energized, and the brakes released. This opens dynamic brake contactors D1 and D2 and gives both motors current through starting resistances.

In the *second position* R1 and R11 contactors close, cutting out one step of resistance from each motor.

Advancing master to third, fourth and fifth and sixth positions picks up the remaining contactors in pairs (one on each panel) until the motors are thrown across the line in parallel.

The series relays are set to drop at normal current so that if the load should go above normal on the sixth position, the relays controlling contactors R5 and R15 would not drop and, although the master may be on the sixth position, the series relays would not permit the motors to be thrown across the line and thus heavily overloaded. Should the motors be running and a heavy overload occur, the load relay would lift, opening the circuit to the accelerating contactors R1. R11, R2, R12, etc., which would insert the starting resistance in series with the motor. This would reduce the current taken by the motor, drop the load relay and permit the motor to come up to a speed under control of the series relays corresponding to about normal current.

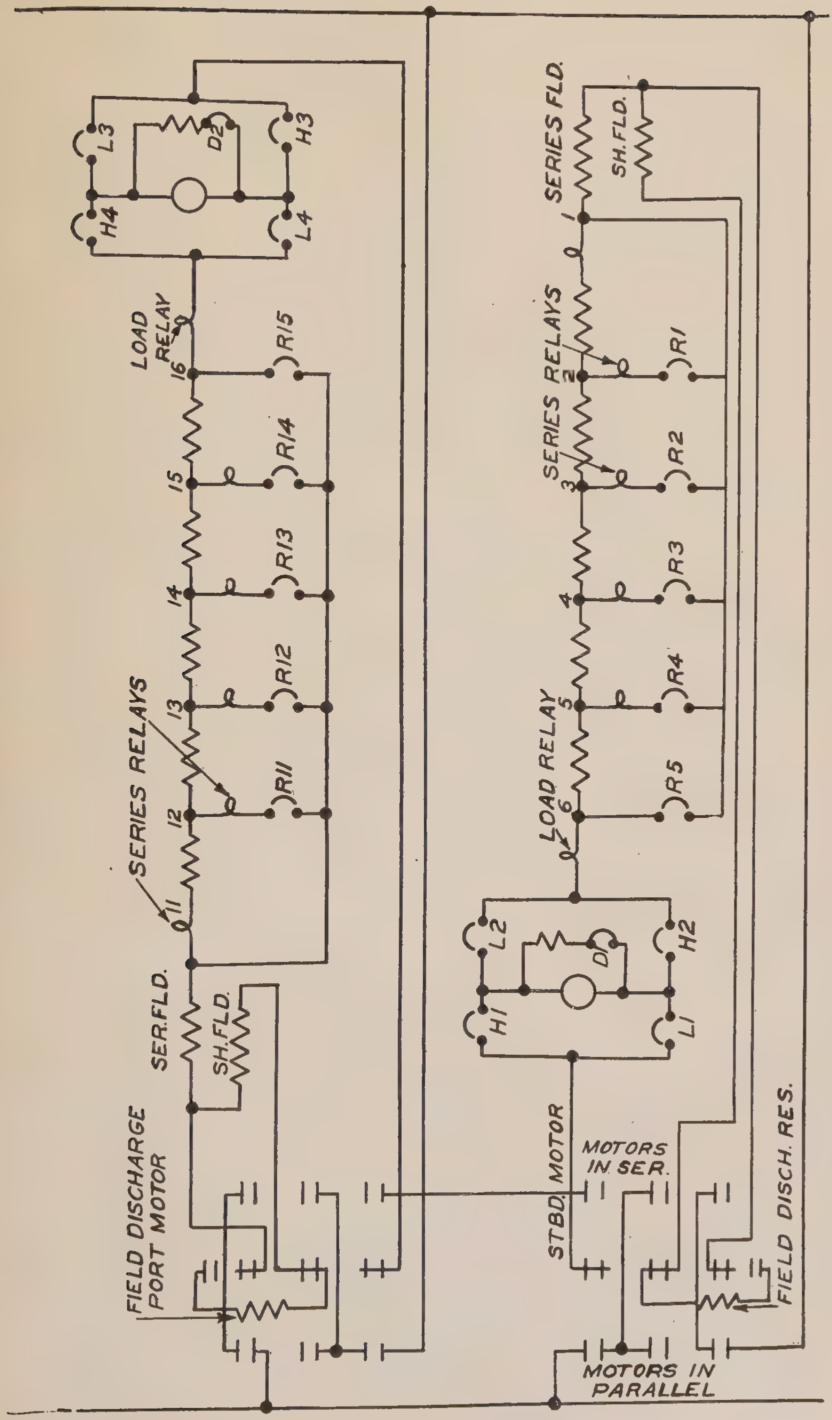

L3
H3
D2
H4
L4
LOAD RELAY
16
R15
15
R14
14
R13
13
R12
12
R11
SERIES RELAYS
11
SER.FLD.
SH.FLD.
FIELD DISCHARGE
PORT MOTOR
SERIES FLD.
SH.FLD.
1
SERIES RELAYS
2
R1
3
R2
4
R3
5
R4
LOAD RELAY
6
R5
L2
H2
D1
H1
L1
STBD. MOTOR
MOTORS IN SER.
MOTORS IN PARALLEL
FIELD DISCH. RES.

FIG. 139.—Elementary Wiring Diagram Anchor Windlass, Contactor-Rheostatic System.

The series relays may be adjusted to any current within the range of the motor capacity.

Operating the master in the reverse direction picks up contactors L1, L2, L3, L4 and the brake contactors, dropping out D1 and D2. This starts the motors in the opposite direction. All of the subsequent operations are as described above.

With the three-blade double-throw switches thrown to position marked "Motors in Series," the operation of the master and contactors will be the same as described above for operation both forward and reverse.

II. Anchor Windlass, Ward-Leonard System.

The principle and operation of the Ward-Leonard system have been fully described under turret turning. The mechanical connections to the windlass and arrangements for independent operation are similar to those just described.

Motors.—The motors are similar to the type just described. They will stand a current of 125 per cent of full-load current with the armature stalled for 15 minutes without injury.

Controlling Appliances.—The equipment consists of:

(1) Two watertight master controllers, reversible.
(2) A panel in three sections.
  (a) Two motor sections which are identical; on each is mounted:
    1. An armature circuit line switch, S1.
    2. A current-limit relay.
    3. A step-back relay.
    4. A series field short-circuiting contactor.
    5. A generator field rheostat contactor.
    6. An ammeter.
    7. A motor field rheostat.
  (b) One switch section on which is mounted:
    1. One 12-pole double-throw switch for selective connection of all master controllers.
    2. Two triple-pole single-throw switches with field discharge clips for field and brake circuits of the motors.
    3. A double-pole single-throw switch with fuses for the control circuits.

Operation.—In this system one of the main generator sets must be used. The voltage applied to the motor brushes is controlled by controlling the field strength of the generator. The generator is separately excited from the ship's regular power service, and the field control is obtained by means of a rheostat manipulated by the operator of the windlass through the master controller.

This system provides all the features of control required and it is not necessary to operate the two motors in series, as the low speed and the high torque obtained by series operation with rheostatic control is obtained by control of the generator voltage.

Referring to the diagram (Fig. 140), each windlass motor armature is connected to the mains from the separately controlled generator by a double-pole single-throw switch (SW 1 and SW 2), with commutating field, series field and two relays in the circuit. The series field is shunted by a contactor, 3, which is closed in lowering the anchor, thus short circuiting the series field and obviating the necessity of using reversing contactors for the same, inasmuch as lowering can be accomplished successfully without the series field. A triple-pole single-throw switch (SW 3-4), is used to connect the shunt field and brake circuits of each motor to the constant potential supply from the regular ship's power service. The shunt fields are provided with discharge resistance; the disc brake coils are not, as the reduced voltage, due to the resistance in series with the coils to make them operate quickly, removes the danger of excessive voltage discharge. Both sides of the disc brakes are brought through these switches in order to allow them to be completely disconnected, if desired.

The control circuits are supplied from the constant potential source by a double-pole single-throw fused switch. All control circuits are brought through the 12-pole double-throw switch in order to connect them to either of the two controllers required. The two small contactors are provided to be operated by the relays whose function will be described later, as the relays themselves are not of sufficient carrying capacity to control the generator field circuit.

In hoisting, the first controller point releases the disc brakes and connects the generator field through all of the resistance to the constant potential ship's mains. This total resistance is arranged to give about 125 per cent of stalled current through the armature of the motor. As this resistance will be different in case of the operation of two motors in parallel or one motor alone, two small switches in series are provided on the motor switches, so that when both motor switches are closed, placing the two motors in parallel, the correct portion of the field rheostat is short circuited. The successive points of the controller cut out portions of the field rheostat, raising the voltage on the motors, hence their speed.

The step-back relays are set to operate between 185 and 200 per cent current on either motor and are in series so that in case one motor is overloaded, the current is limited. When either of the step-back relays operate, the contactor controlled by it is opened thus inserting all of the generator field resistance and reducing the voltage to the point where about 125 per cent stalled current is produced. When the current has fallen below this

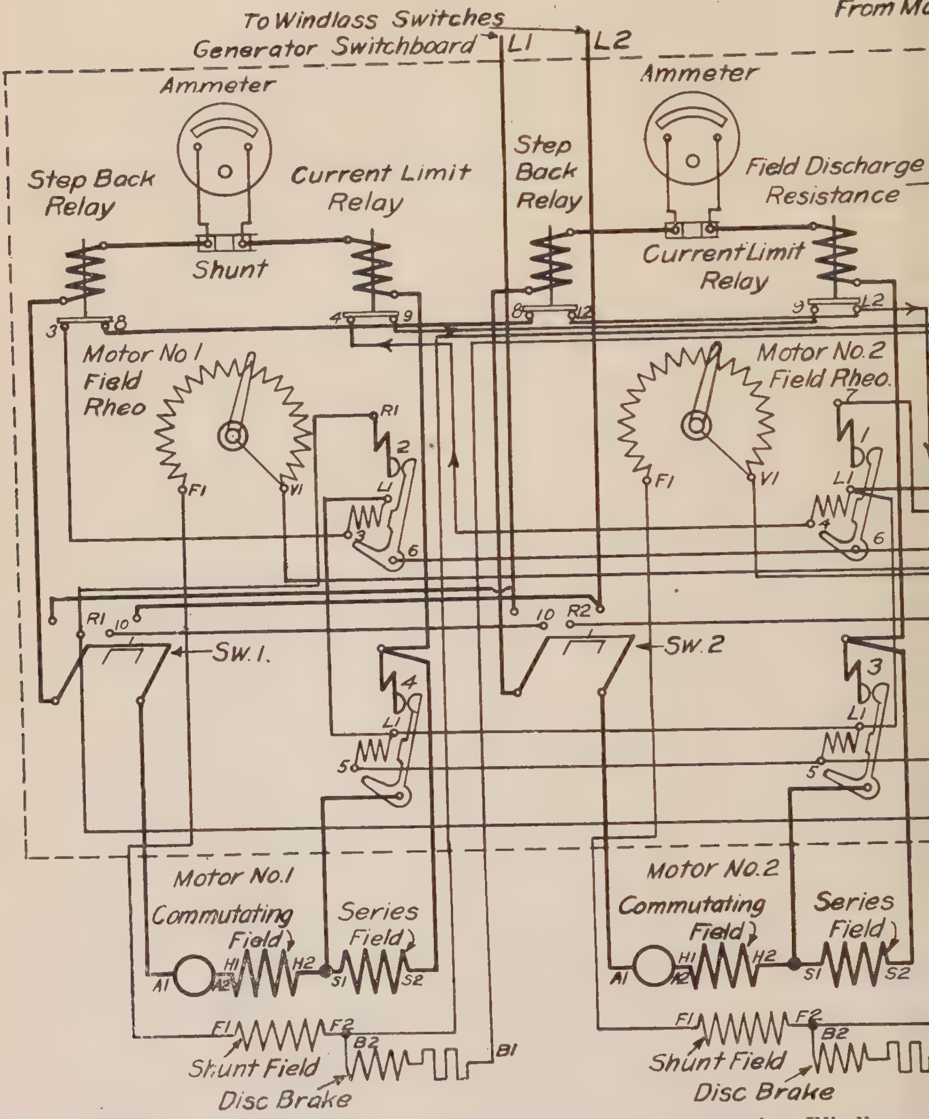
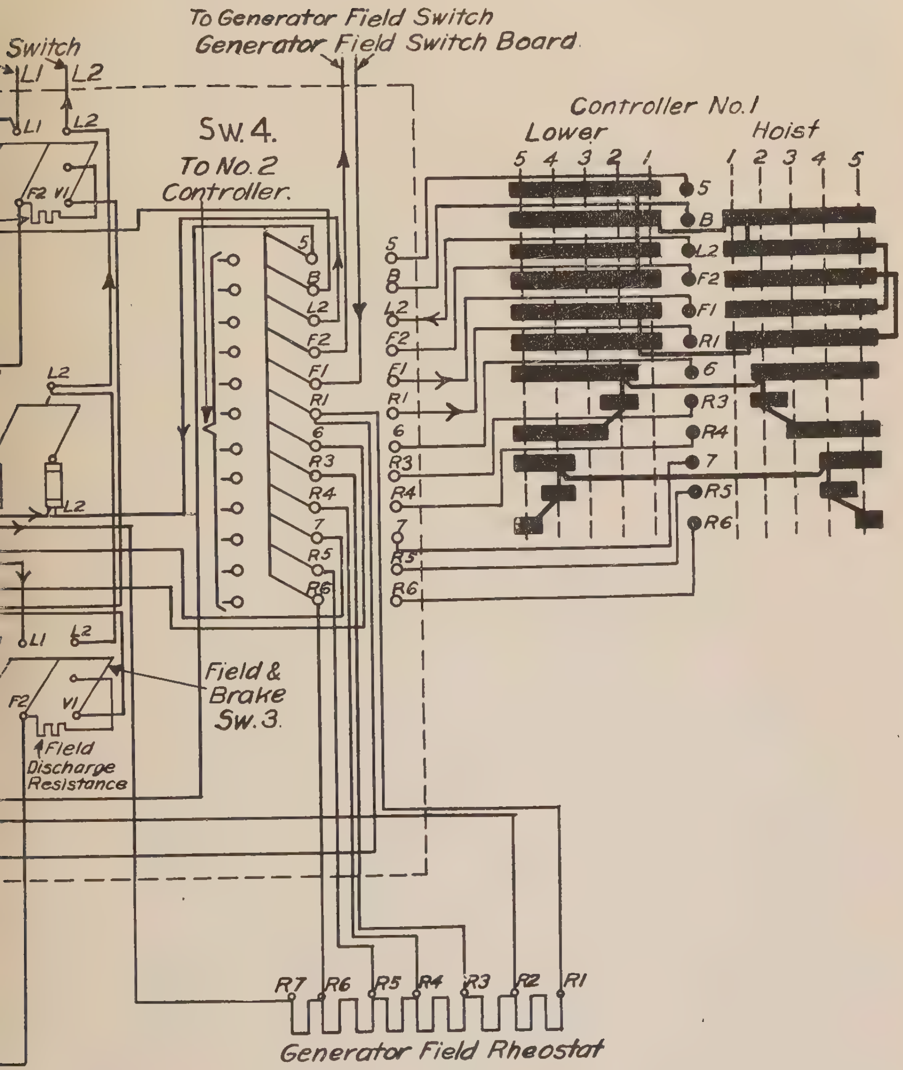

To Windlass Switches
Generator Switchboard
L1
L2
From Mo
Ammeter
Step Back Relay
Current Limit Relay
Shunt
Ammeter
Step Back Relay
Field Discharge Resistance
Current Limit Relay
3
8
4
9
8
12
9
L2
Motor No 1 Field Rheo
Motor No. 2 Field Rheo.
F1
V1
R1
2
L1
3
6
F1
V1
1
L1
4
6
R1
10
Sw. 1.
10
R2
Sw. 2
4
L1
5
3
L1
5
Motor No. 1
Commutating Field
Series Field
A1
A2
H1
H2
S1
S2
F1
F2
B2
B1
Shunt Field
Disc Brake
Motor No. 2
Commutating Field
Series Field
A1
A2
H1
H2
S1
S2
F1
F2
B2
Shunt Field
Disc Brake

FIG. 140.—Anchor Windlass.


To Generator Field Switch
Generator Field Switch Board
Switch
L1
L2
L1
L2
Sw. 4.
To No. 2 Controller.
F2
V1
Controller No. 1
Lower
Hoist
5 4 3 2 1
1 2 3 4 5
5
B
L2
F2
F1
R1
6
R3
R4
7
R5
R6
L2
L2
L1
L2
F2
V1
Field & Brake Sw. 3.
Field Discharge Resistance
R7
R6
R5
R4
R3
R2
R1
Generator Field Rheostat

ard System. Wiring Diagram.

point, the step-back relay is automatically reset, closing the contactor which cuts out part of the resistance of the generator field. It should be noted that only part is cut out immediately, because there are provided two current-limit relays, also in series, operating a second contactor. The current-limit relays operate at the same time as the step-back relays but are reset at a lower current and thus prevent all of the resistance up to the point for which the controller is set, being cut out at one time. If the controller were set at, say the fifth position, and if the step-back relay operated and again reset, and all of the resistance in the generator field were cut out at one time, the acceleration would be very rapid, and a peak current sufficient to again operate the step-back relay might occur. In lowering, the operation is similar except that on the first position of the controller the contactors short circuiting the series fields of the motors are closed. The reversal of the motor is accomplished by reversing the excitation of the generator.

The disc brake may be released, in order to turn the motors over by hand, by closing the double-pole and triple-pole single-throw switches and putting the controller on the first position. The motor switches should, of course, be left open.

STEERING GEAR.

Electrically operated steering gear has been introduced on recent battleships and is included in the design of those building.

Requirements.—A steering-gear equipment must fulfill the following requirements:

1. Start under any conditions of load, or position of the rudder when the controller handle is moved to any running position.
2. Must be capable of withstanding large and frequent changes of speed and load, starting, stopping and reversing with certainty of operation, and without damage.
3. Stop and hold rudder when controller handle is brought to "off" position from any other position.
4. Stop if operator takes his hand off controller handle.
5. Be provided with arrangement to limit travel, to prevent jamming with rudder hard over.
6. Have provision for operation from several stations.

Electrically operated steering gear does not include the "follow-up" provision as in steam-driven equipment, but the motor revolves, turning the rudder as long as the operating lever is held in one of the running positions.

There are three systems that have been installed, or will be installed in ships building:

1. Contactor-rheostatic system.
2. The Ward-Leonard system.
3. Hydraulic speed-gear system.

I. Contactor-Rheostatic System.

In this system the steering-gear mechanism is operated entirely by means of electrical equipment in place of the steam engine. In recent battleships two motors, each 150-horsepower capacity, are used. The motors obtain their power direct from the dynamo-room feeders through the controlling apparatus.

The motors operate the steering-gear mechanism through reduction gearing.

Both motors are mounted on a common bed plate.

Motors.—These are Diehl motors, type K, 120 volts, 150 horsepower. They are of the open-type, eight-pole compound-wound, interpole.

BRAKES.—The brakes, manufactured by the Cutler-Hammer Company, are similar to those on the windlass and capstan, differing only in that they are series connected.

Controlling Appliances.—The controlling appliances were manufactured by the Cutler-Hammer Manufacturing Company, and consist of a main-contactor panel with necessary resistances, a limit switch, and four master controllers or steering stands, located, one at each of the following places: steering platform, conning-tower, central station and steering-gear room.

MAIN-CONTACTOR PANEL.—This panel is divided into two sections to facilitate installation. Each section consists of an impregnated asbestos lumber panel carrying on the front the necessary contactors and series relays, together with their interlocking contacts, an overload relay (styled 7 prong), brake relay, reversing-switch relays and control-circuit relay. In addition to the above there is provided a dial type selective switch by means of which the "control" may be assigned to any one of the four steering stands. The design of this selective switch is such that it is impossible to operate the electric steering gear from more than one station at the same time.

The contactors are of rugged construction provided with laminated contacts and also with arc rupturing, readily renewable auxiliary contacts. They are very similar to those used with the windlass.

LIMIT SWITCH.—The limit switch consists of an iron frame with removable sheet-metal cover and a cylinder provided with contact segments which make contact with controller fingers mounted on a finger board that is secured to the back of the case. The drum is mounted on a shaft which projects through one end of the case. Motion is transmitted by means of a lever fitted on this end of the shaft, this lever being operated by rollers or dogs secured to sliding nuts, on the screw gear. This switch operates at the extreme limits of travel of the rudder. When either roller has engaged the limit-switch lever, a further movement of 7/16″ is required to operate the switch.

The secondary circuits from the contactor panel to the main controller are connected in series with this switch. When the rudder is turned hard over, one of these circuits, depending on the position of the rudder, port or starboard, is opened and the motors are stopped. Further movement cannot be made in this direction, but the rudder may be operated in the opposite direction by reversing the master controller. When the rudder moves away from the extreme limit position, the switch automatically returns to its normal (central) position by means of the centering spring.

MASTER CONTROLLER.—As previously mentioned, there are four master controllers or steering stands. These are all of similar construction, except that the one located at the steering platform is made watertight. The controller is a reversing drum controller supported on a two-inch brass gas pipe provided with a flange at the bottom. The operating lever is provided with a latching device which, in addition, indicates each of the running positions and the "off" position. A centering spring acts to return the lever to the "off" position. Should the hand be removed from the lever in any running position it will quickly return to the "off" position.

The design is such that a small movement of the lever causes the segment to engage the first finger, thus starting the motors and running them at slow speed. A further, relatively large, angular movement acts to accelerate the motors up to full speed. Moving the lever in the opposite direction reverses the rotation of the motors. The controllers are provided with three speeds in each direction. The first position is with both motors connected in series with all resistance in circuit, the second is the same with all resistance cut out, and the third is with both motors connected in parallel with all resistance cut out.

OVERLOAD DEVICE.—The overload device, styled 7 prong, consists of a solenoid coil actuating a core which operates to move a small pivoted stud. This stud carries four segments which make contacts during the upward and downward movement of the plunger. In case of extreme overloads this device automatically, by means of the above contacts, limits the current on the motors to a safe value. In consequence of the above the necessity for circuit breakers and fuses is obviated.

Operation and Description of Circuits.—Referring to diagram of electrical connections, Fig. 143, and elementary diagram of control circuits, Figs. 141 and 142, the operation will be studied by considering the conning-tower master to be thrown to the left on control speeds 1, 2 and 3, and each circuit with the corresponding operation will be described.

A.

Moving the master to the first position makes circuit 31-32 (elementary diagram 1-2), closing the shunt solenoid coil to switch marked B.

(A1) Closing of switch B energizes contactors B1, B2, B3 and B4 through the limit switch. The other side of switch B closes the circuit to S through the PR relay, and to BK through the contacts D1, R4, BR relay and PR relay. The closing of contactors B1, B2, B3, B4 and S puts the two motors across the line in series with all of the resistances, giving about 75 per cent normal current. (See elementary diagram motor circuits, Fig. 142.)

(A2) The closing of contactors B1 and B3 opens the circuit to the dynamic brake contactors D1 and D2, causing these contactors to open and to remain open as long as B1 and B3 remain closed.

B.

Advancing the conning-tower master to second position closes contact 31-34, closing the AR relay (see Fig. 143), through the overload switches and auxiliary switches on the top of contactors B4 and B2, and also closes the circuit to the shunt spools on the overload relays through resistance EF and the auxiliary switches on the top of contactors B4 and B2.

(B1) Closing AR relay (Fig. 141), closes one side of the circuit to R1, R2, R3, R4, R12 and R13, which switches operate in the following sequence:

(*a*) Switch R1 closes as soon as AR relay closes, cutting out resistance 4-5, giving the motor about 150 per cent normal current, causing series relay No. 1 to lift.

(*b*) The rush of current due to R1 closing will decrease as soon as motor speeds up, allowing series relay No. 1 to drop which completes the circuit to accelerating switch R2 through the auxiliary switch on the top of contactor R1, giving the motor the second rush of current and lifting series relay No. 11.

(*c*) As soon as the current due to R2 closing has decreased to about normal, series relay No. 11 closes the circuit to accelerating switch R12 through the auxiliary switch on the top of R2, giving the motor another rush of current, lifting series relay No. 2.

(*d*) As soon as this current has decreased to about normal, series relay No. 2 drops closing the circuit to accelerating switch R3 through the auxiliary switch on the top of R12, giving the motor another rush of current, lifting series relay No. 12.

(*e*) As soon as this current has decreased to normal, series relay No. 12 drops and closes accelerating switch R13 through the auxiliary switch on the top of R3, lifting series relay No. 13.

(*f*) As soon as the motor current has again decreased to normal, series relay No. 13 drops and closes the circuit to R4 through the auxiliary switch on the top of R13. Accelerating switch R4 places the motors in series across the line.

C.

Advancing the conning-tower master to the third or full-speed position closes circuit 31-35, elementary diagram 1-5, energizing PR relay through the auxiliary switch on the top of contactor R4, the overload switches, and the auxiliary switches on the top of contactors B4 and B2.

(C1) Closing of PR relay lifts the four normally closed fingers and closes the normally open fingers in the following sequence:

(*a*) Fingers making circuit to S, R2, R12, R3 and R13 lift simultaneously, opening all of these contactors.

(*b*) Finger to contactors P1 and P2 closes, closing the paralleling switches, throwing the motors across the line in parallel, each motor in series with two steps of resistance, while R4 is still closed, thus preventing the motors from losing torque during the change-over.

(*c*) Finger to contactor R4 opens.

(*d*) Finger to contactors R2, R12, R3 and R13 close simultaneously.

Series relays No. 1 on the upper motor (see elementary diagram motor circuits) and No. 11 will be up due to the rush of current through the motors when thrown across the line in series with the resistance, and as soon as motors have increased in speed sufficiently to bring the current in each motor to about normal, series relays No. 1 and No. 11 drop, closing accelerating switch R2 for the upper motor through the auxiliary switch on the top of R1, and accelerating switch R12 for the lower motor through the auxiliary switch on the top of R2, giving each motor a rush of current and lifting series relays R2 for the upper motor and R12 for the lower motor.

(*e*) As soon as the current has decreased to about normal, series relays No. 2 and No. 12 drop, closing accelerating switch R3 for the upper motor through auxiliary switch on the top of R12, and R13 for the lower motor, through the auxiliary switch on the top of R3, placing the two motors in parallel across the line.

D.

Returning the conning-tower master to the "off" position without pause on any of the fingers, all of the relays drop, also all of the contactors and as soon as the auxiliary switches on the top of B4 and B2 close, the dynamic brake switches D1 and D2 close, short circuiting the armatures through the dynamic brake resistances.

When returning the conning-tower master to the "off" position one step at a time and remaining on each step long enough for the complete operation of the controller, the sequence is as follows:

Moving the conning-tower lever from the third to the second position opens the circuit 31-35, Fig. 143, opening PR relay which opens three normally open fingers and closes the four normally closed fingers.

(a) Fingers to contactors R2, R12, R3 and R13 open and close without opening these switches. Finger to P1 and P2 opens at the same time finger to R4 closes, but as the opening of contactors takes about half the time of the closing of contactors, P1 and P2 will completely open before R4 closes. As soon as finger to R4 closes it closes the circuit to the brake relay through the series relay BK, the auxiliary discs on the top of R4 and D1 closing this circuit, and a current of about 200 amperes is maintained through the series brakes, which keep these brakes from setting during the time the motor circuit is open. This clapper switch BK is energized about the same time that switches P1 and P2 are de-energized, so that the switch BK closes, holding the circuit through the brake before the switches P1 and P2 have had time to open the motor circuit which would allow the brakes to set. As soon as R4 closes, throwing the motors across the line in series, this BK switch will be opened by means of the auxiliary switch on the top of R4.

E.

Returning the conning-tower master from the second to the first position opens circuit 31-34, elementary diagram 1-4, thus opening the AR relay.

(a) The opening of AR relay opens the circuit to all of the accelerating switches, inserting all of the armature resistance in series with the two motors in series across the line, giving the motors about 75 per cent normal current.

F.

Returning the conning-tower master to the "off" position from first position opens circuit 31-32, elementary diagram 1-2, which opens relay B which relay de-energizes the contactors B1, B2, B3, B4 and S. The opening of these contactors closes the auxiliary switches on the top of B4 and B2 which completes the circuit to the dynamic brake contactors D1 and D2, short circuiting the motor armatures through the dynamic brake resistances.

G.

Moving the conning-tower master to the first position to the right closes circuit 31-33, Fig. 143, and closes relay marked F.

(a) Closing of relay F closes the circuit to contactors F1, F2, F3 and F4 through the limit switch. The other side of relay F energizes contactor S, also BK through the auxiliary discs on the top of D1 and R4 and BK relay, throwing the motors across the line in series with all of the resistances giving about 75 per cent normal current. All of the subsequent operations are as described above for moving of conning-tower master to the left.

Should the conning-tower master be moved from the "off" to the third position without pause on any of the fingers, operation of the controller

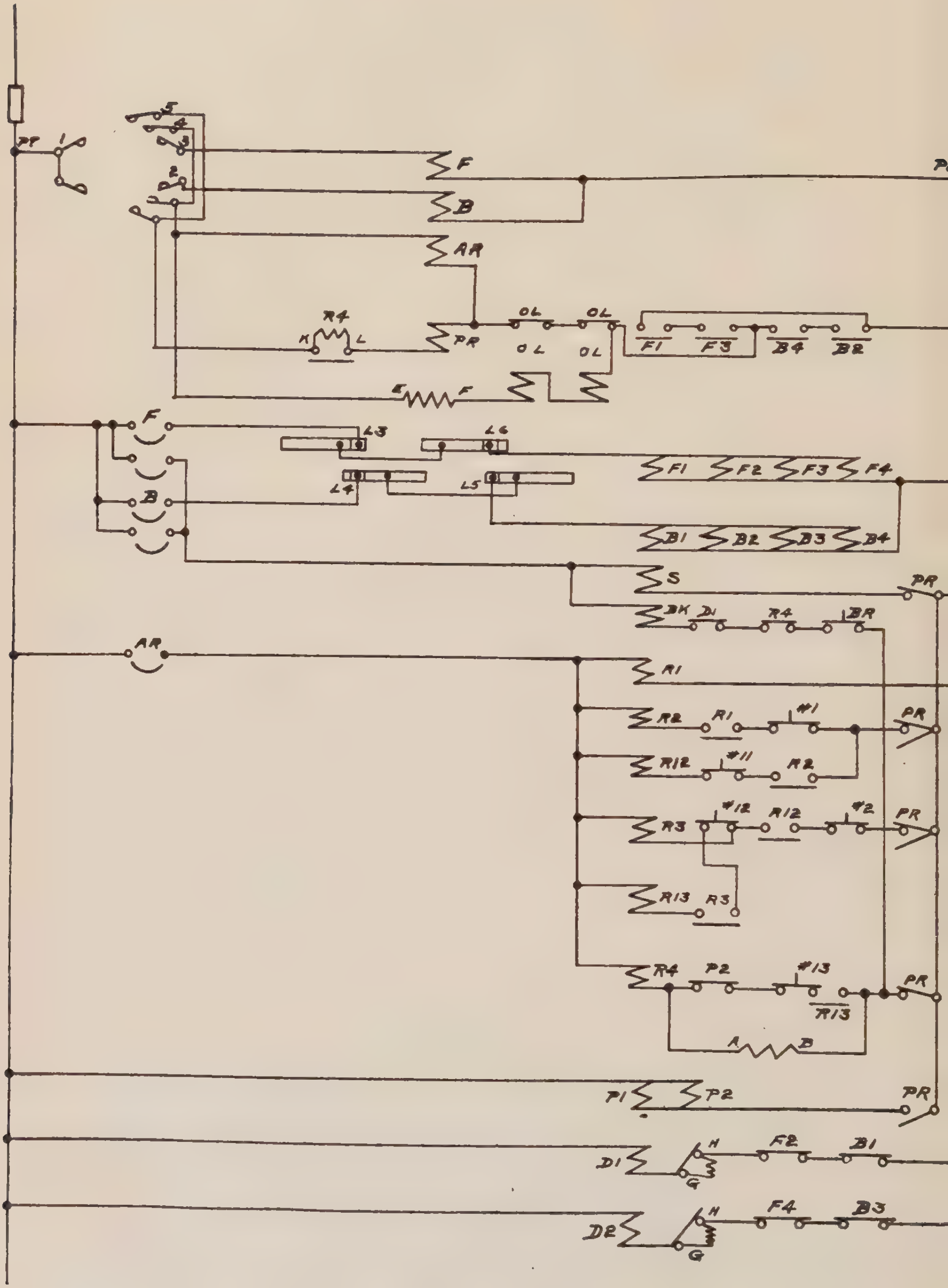
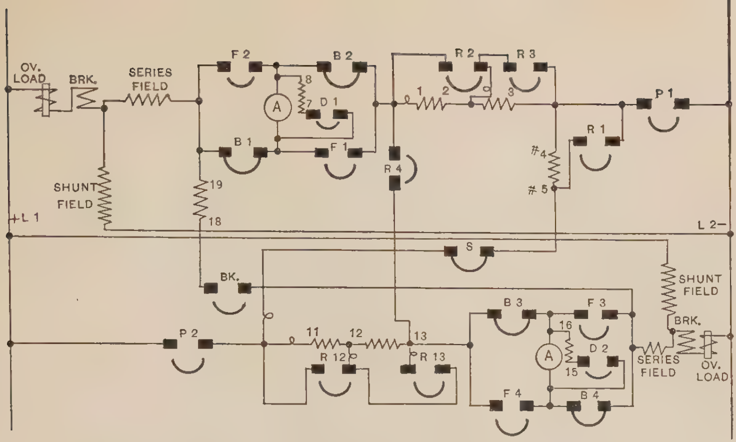
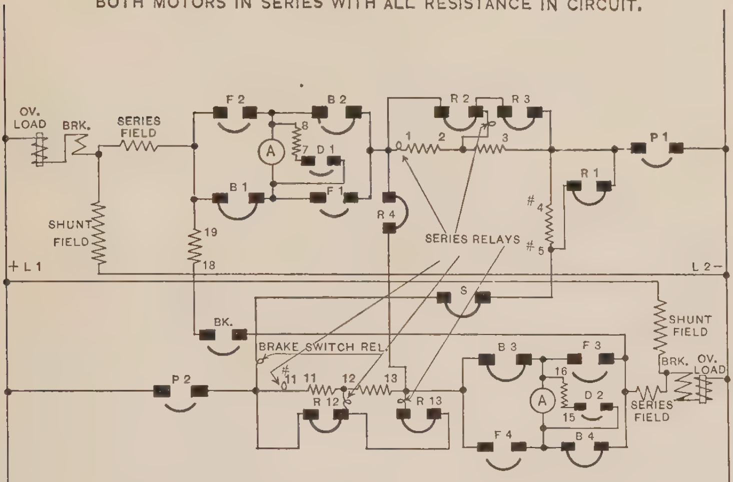

PT
1
5
4
3
2
F
B
AR
R4
K
L
PR
OL
OL
OL
OL
F1
F3
B4
B2
E
F
F
L3
L6
L4
L5
B
F1
F2
F3
F4
B1
B2
B3
B4
S
PR
BK
D1
R4
BR
AR
R1
R2
R1
#1
PR
R12
#11
R2
R3
#12
R12
#2
PR
R13
R3
R4
P2
#13
PR
R13
A
B
P1
P2
PR
D1
H
F2
B1
G
D2
H
F4
B3
G

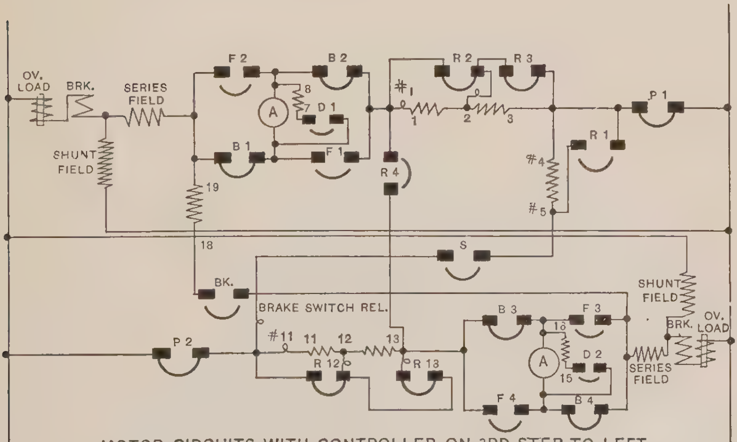
FIG. 141.—Steeiing Gear, Contactor-Rheostatic System, Elementary Diagram of Control Circuits.


OV. LOAD
BRK.
SERIES FIELD
F 2
B 2
A
8
7
D 1
B 1
F 1
R 2
R 3
1
2
3
P 1
R 1
R 4
#4
#5
SHUNT FIELD
19
18
+L 1
L 2−
S
BK.
SHUNT FIELD
BRK.
B 3
F 3
16
D 2
15
P 2
11
12
13
R 12
R 13
SERIES FIELD
OV. LOAD
F 4
B 4

MOTOR CIRCUITS WITH CONTROLLER ON 1ST STEP TO LEFT, BOTH MOTORS IN SERIES WITH ALL RESISTANCE IN CIRCUIT.


OV. LOAD
BRK.
SERIES FIELD
F 2
B 2
A
8
7
D 1
B 1
F 1
R 2
R 3
1
2
3
P 1
R 1
R 4
#4
SERIES RELAYS
#5
SHUNT FIELD
19
18
+L 1
L 2−
S
BK.
SHUNT FIELD
BRAKE SWITCH REL.
BRK.
OV. LOAD
B 3
F 3
16
D 2
15
P 2
#11
11
12
13
R 12
R 13
SERIES FIELD
F 4
B 4

MOTOR CIRCUITS WITH CONTROLLER ON 2ND STEP TO LEFT, BOTH MOTORS IN SERIES WITH ALL RESISTANCE CUT OUT.


OV. LOAD
BRK.
SERIES FIELD
F 2
B 2
A
8
7
D 1
B 1
F 1
R 2
R 3
#1
1
2
3
P 1
R 1
R 4
#4
#5
SHUNT FIELD
19
18
S
BK.
SHUNT FIELD
BRAKE SWITCH REL.
BRK.
OV. LOAD
B 3
F 3
16
D 2
15
P 2
#11
11
12
13
R 12
R 13
SERIES FIELD
F 4
B 4

MOTOR CIRCUITS WITH CONTROLLER ON 3RD STEP TO LEFT BOTH MOTORS IN PARALLEL WITH ALL RESISTANCE CUT OUT.

OPERATING THE CONTROLLER IN THE OPPOSITE DIRECTION ALL CONNECTIONS ARE THE SAME EXCEPT, F1, F2, F3 & F4 CLOSE IN PLACE OF B1, B2, B3 & B4.

Fig. 142.—Steering Gear, Contactor-Rheostatic System, Elementary Diagram of Motor Circuits.

would take place as described above for the movement of the master one position at a time automatically. The resistance KL in series with PR relay will not permit this relay to close until accelerating switch R4 has short circuited this resistance, which is the proper time for the PR relay to function. The resistance AB in circuit with accelerating switch R4 prevents R4 from opening when PR relay makes the change-over, opening contactors R2, R3, R12 and R13. Resistance GH in series with D1 and D2 is used to prevent the solenoid spools from overheating as these contactors remain closed when power is on the steering-gear switchboards.

In case of overload when master controller is in the second or third position, the overload relays function to make the connections of the first position or the two motors in series with all of the resistance.

In case of failure of voltage, all the contactors will open, stopping the motors immediately. Upon the return of voltage to the line the controller will automatically bring the motor to the position in which the master controller is being held.

PR relay has a range of operation of about $\frac{3}{4}$ to 4 seconds, but will operate to the best advantage in about $1\frac{1}{2}$ seconds.

II. Steering Gear—Ward-Leonard System.

The application of the Ward-Leonard system in this case is similar to that of the anchor windlass with the addition of limit switch, selective switch and several steering stands to meet the special requirements in this case. The selective switch is similar to the one described in the "Rheostatic System."

A motor generator is used to supply the current for the steering-gear motor. The motor (of the motor generator) is *compound* wound and the generator is *differential* wound, so that, at extreme overloads, the voltage of the generator will be reduced by reduction of speed and by the demagnetizing effect of the armature and series field of the generator; also the reduction of the speed will deliver considerable energy for a few seconds to the rudder motor.

The steering-gear motor is compound wound and the shunt field is strengthened by a relay at a definite overload on the motor. This system should have the advantages of avoiding peaks of load when the motor is started and of giving possibly more reliable operation with less attention for replacements and repairs under long service. It has the disadvantage of the additional weight and cost of a motor generator which requires power to operate, even when the rudder is not being moved.

III. Steering Gear—Hydraulic Speed-Gear System.

The A-ends of two hydraulic speed gears are operated by either of two 75-horsepower motors in the steering-gear compartment. These motors are controlled by contactor controlling appliances, starting duty only. A "hand trick wheel" in the steering-gear compartment operates a control shaft that, through the speed gears, controls the speed and direction of motion of the rudder. In steering from the bridge or other distant station the trick wheel shaft is turned by one of two pilot motors connected to it by spur gearing and arranged so that the pinion on the motor shaft can be slid in or out of mesh with a gear on the trick wheel shaft. The pilot motor in use is controlled by a standard master controller of the non-follow-up type at the steering station. The safety arrangements as described in conjunction with other types of steering-gear apparatus are provided for by modifications of the hydraulic speed gear.

Auxiliary drive is provided for: (1) by hand, (2) through a 5-horsepower motor taking current from the regular ship's power circuits, and (3) through a 5-horsepower, 80-volt electric motor. The power for this motor is furnished by a storage battery.

CHAPTER IX.

MOTIVE POWER FOR GENERATORS.

The only motive power that has been used on board ships of the navy for driving electric generators is steam, with the exception of that for motor generators, which is, of course, electric power. Experiments were made at one time with water motors as a source of power for generator driving, and, although good results were obtained, it never was adopted or tried under service conditions.

Reciprocating engines were installed and are still in use in the older ships, but all recent installations are driven by steam turbines. Owing to the comparative high speed desirable for generators, many difficulties arose with reciprocating engines that are eliminated with turbine drive. The equipment on a number of battleships consists of four 300 kw., 1500 R. P. M., direct-connected, turbine-driven generators. Beginning with the *Arizona* geared turbines were used. There are four 300 kw. generators, making 900 R. P. M., driven through gearing by turbines making 6000 R. P. M. on that vessel. As the vacuum in the auxiliary exhaust line is usually poor, separate dynamo condensers are usually installed. Uniform speed of the generator is necessary and for this reason governors are fitted on all engines.

Steam Supply.—The steam supply to the dynamo room in older ships was led direct from certain boilers, or all of them, with separate stop valves on the boilers. This was to insure dry steam to the fast-running reciprocating engines. In later installations, the steam supply is taken from the auxiliary steam line to the dynamo room, but the leads are made direct and with few or no branches to other auxiliaries. There are usually two supply lines, one from the auxiliary line on each side of the ship leading to a common pipe in the dynamo room. This is in order to get steam to the dynamo room if either line is cut out for repairs, or due to accident.

From this common pipe the steam passes through a reducing valve, to reduce the boiler pressure to the working pressure of the generator engines and to insure an even steam pressure. It then passes through a steam separator in which any water is separated from the steam, then through branch pipes to the engines. There is a stop valve on each branch in addition to the throttle valve at the engine. Branches are taken from the main supply line for steam to the air and circulating pumps and hot-well pump.

The dynamo exhaust leads to the dynamo condenser (when installed) with separate connections by which the exhaust can be sent to the auxiliary exhaust line or to the atmosphere or, in some installations, direct to a main condenser.

The path of steam from the boiler through the generator engine and back to the boiler is shown in Fig. 144.

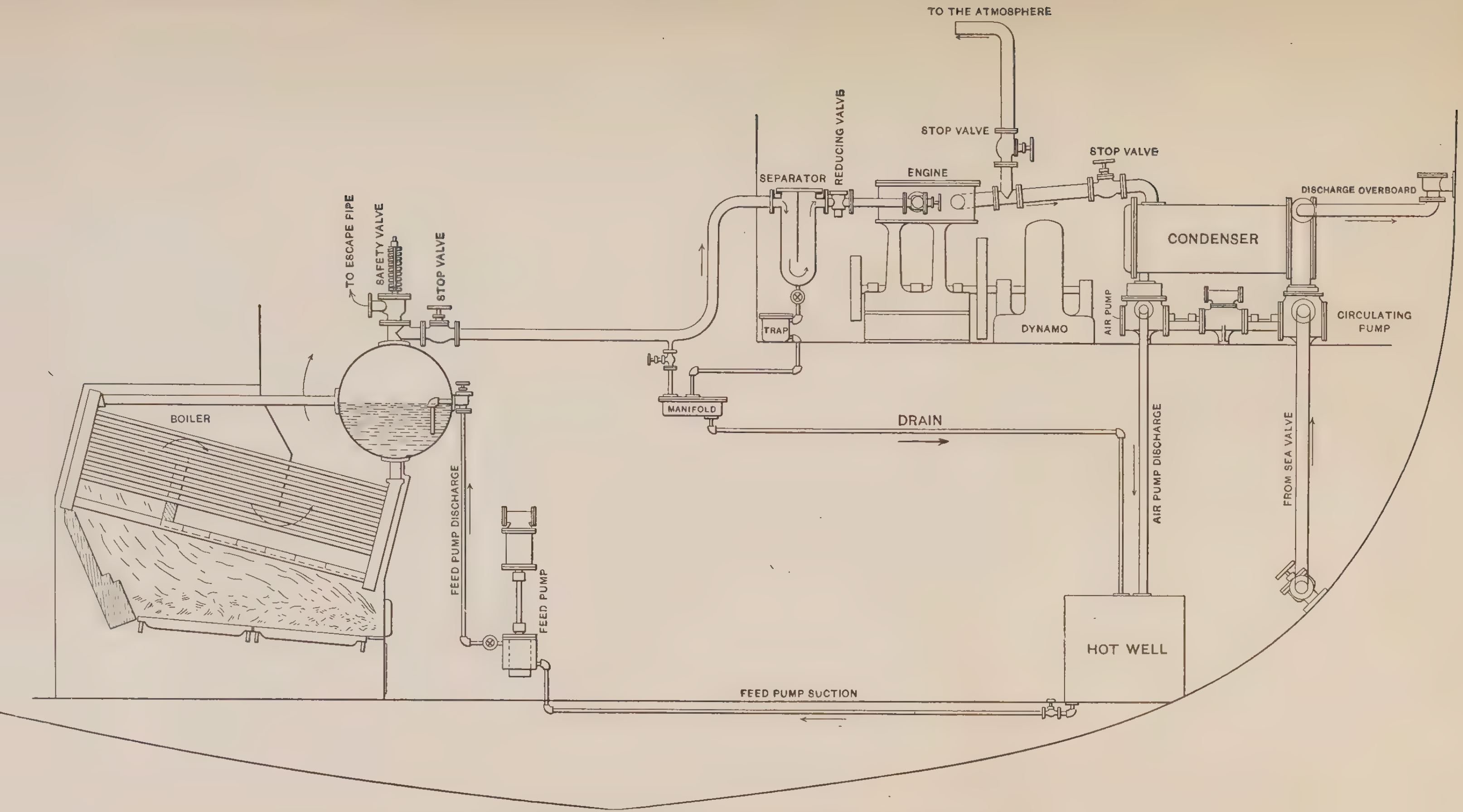
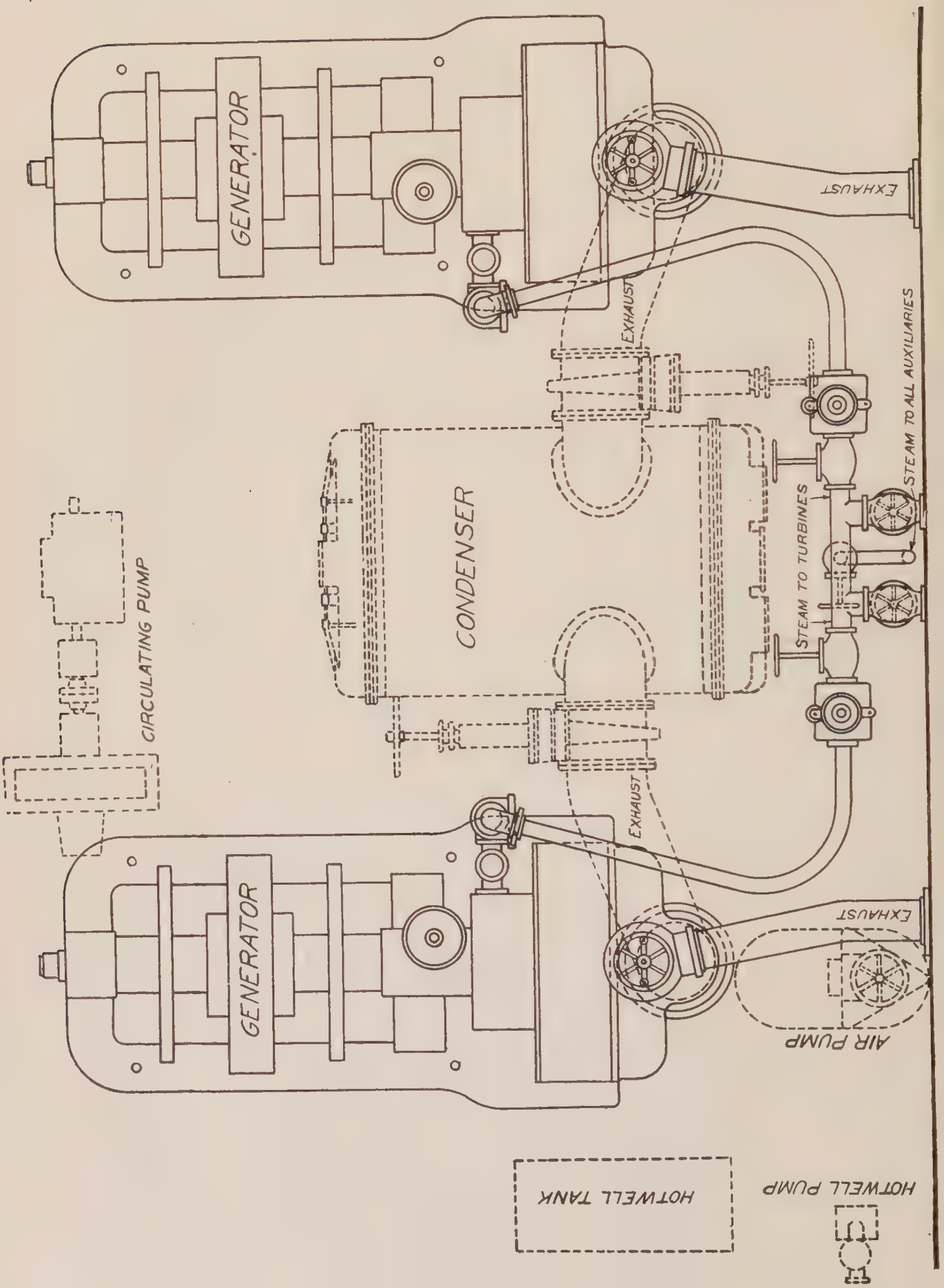

TO THE ATMOSPHERE
STOP VALVE
STOP VALVE
REDUCING VALVB
ENGINE
SEPARATOR
TO ESCAPE PIPE
SAFETY VALVE
STOP VALVE
DISCHARGE OVERBOARD
CONDENSER
CIRCULATING PUMP
AIR PUMP
DYNAMO
TRAP
MANIFOLD
BOILER
DRAIN
AIR PUMP DISCHARGE
FROM SEA VALVE
FEED PUMP DISCHARGE
FEED PUMP
HOT WELL
FEED PUMP SUCTION

FIG. 144.—Path of Steam from Boilers to Generator Engines.


GENERATOR
EXHAUST
EXHAUST
STEAM TO ALL AUXILIARIES
CONDENSER
CIRCULATING PUMP
STEAM TO TURBINES
EXHAUST
GENERATOR
EXHAUST
AIR PUMP
HOTWELL TANK
HOTWELL PUMP

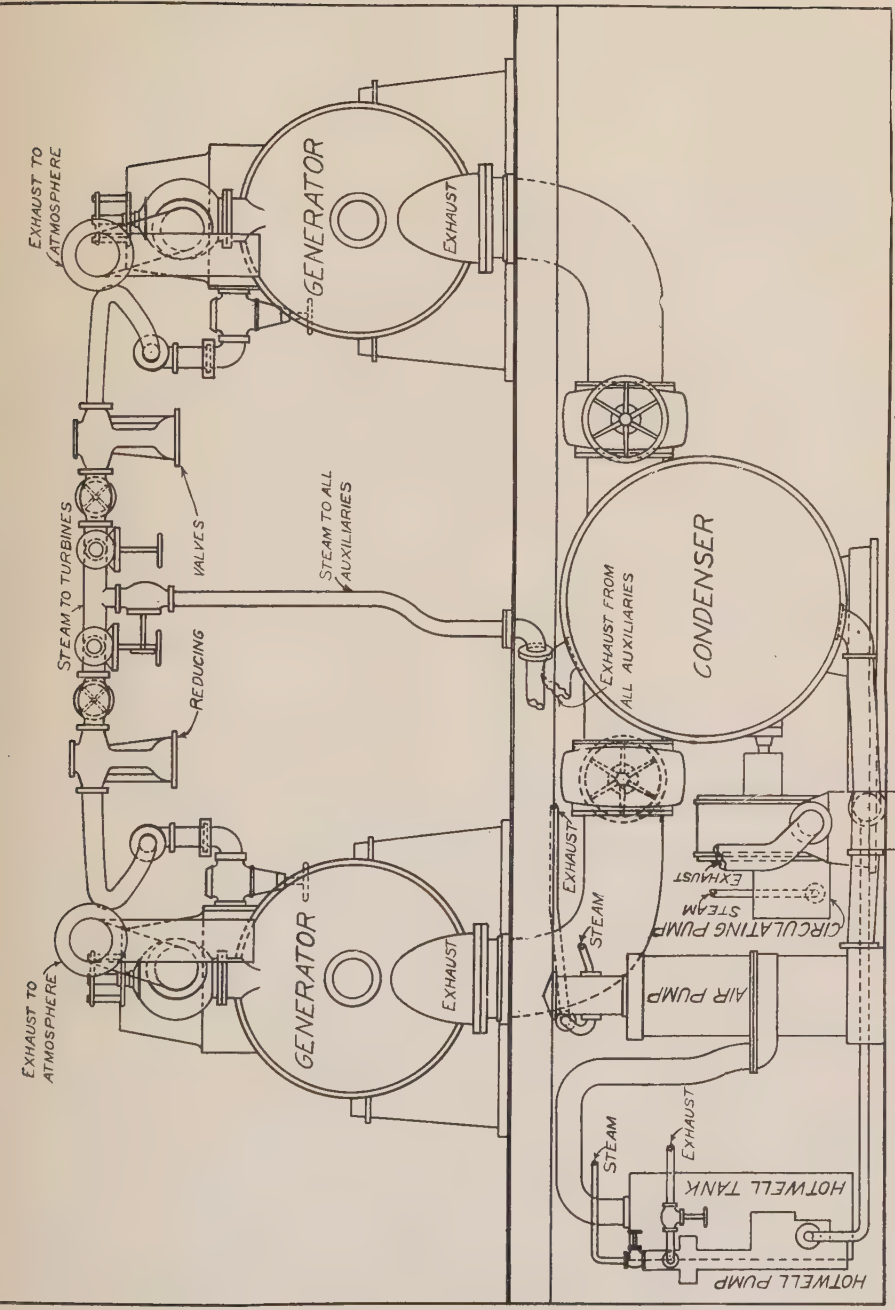

EXHAUST TO ATMOSPHERE
GENERATOR
EXHAUST
VALVES
STEAM TO TURBINES
STEAM TO ALL AUXILIARIES
REDUCING
EXHAUST TO ATMOSPHERE
GENERATOR
EXHAUST
CONDENSER
EXHAUST FROM ALL AUXILIARIES
EXHAUST
STEAM
EXHAUST
STEAM
CIRCULATING PUMP
AIR PUMP
STEAM
EXHAUST
HOTWELL TANK
HOTWELL PUMP

FIG. 146.—Forward Dynamo and Condenser Rooms. (Elevation.)

In recent battleships there are two dynamo rooms, one forward and one aft, each with two 300 kw. turbo-generators. The exhaust from the forward dynamo room leads to a separate condensing plant in a compartment immediately below it. The exhaust from the after dynamo room leads to its own condensing plant or, in some installations, direct to one of the main condensers.

Figs. 145 and 146 show plan and elevation of the installation in the forward dynamo and condenser rooms of a recent battleship.

RECIPROCATING ENGINES.

A number of types of reciprocating engines were used on the early ships, but all the later ones were vertical inverted two-cylinder compound engines. All are fitted with reducing valves in the steam line to give uniform steam pressure and governors to further insure uniform speed.

General Electric Engine, Form H2 (Fig. 147).

This form of engine is one of the latest reciprocating engine types made by the General Electric Company, and many of this design will be found on our older ships of war. This form of engine is used with generators up to 100 kw. capacity. All dimensions given are for the engine of the 100 kw. generating set.

Steam Pressure.—The range of steam pressures for this engine is between 120 and 180 pounds, with a normal pressure of 150 pounds, and 25-inch vacuum. The engine will carry an overload of 33⅓ per cent without trouble. It is advisable to maintain normal steam pressure, if possible.

Cylinders.—The cylinders are 10 and 18 inches with a stroke of 10 inches. The high-pressure and low-pressure cylinders are separate castings of hard, close-grained cast iron. The high-pressure cylinder and steam chest are in one casting; the low-pressure steam chest is bolted to the low-pressure cylinder.

The receiver, forming a part of the cylinder castings, conveys the exhaust steam from the high-pressure cylinder to the low-pressure steam chest.

Both cylinders have relief valves and are tapped for drain and indicator valves.

Steam Distribution and Valves.—The steam distribution is accomplished through one high-pressure, cast-iron, balanced piston valve A, and one low-pressure, flat, partially balanced slide valve fitted with relief ring to reduce friction. Timed by the movement of valve A, the steam enters the high-pressure cylinder chest and valve in proper quantities through the throttle valve, and after doing its work in the high-pressure cylinder, is exhausted to receiver, admitted to the low-pressure cylinder by valve B, and finally exhausted through passage D.

High-Pressure Valve.—The high-pressure valve takes steam on the inside, the admission edges being at E, and the exhaust edges at F.

The travel of this valve is controlled by the automatic governor, and varies between $3\frac{3}{4}$ and $1\frac{5}{8}$ inches. The cut off varies between $\frac{3}{4}$ and 0, depending upon the load.

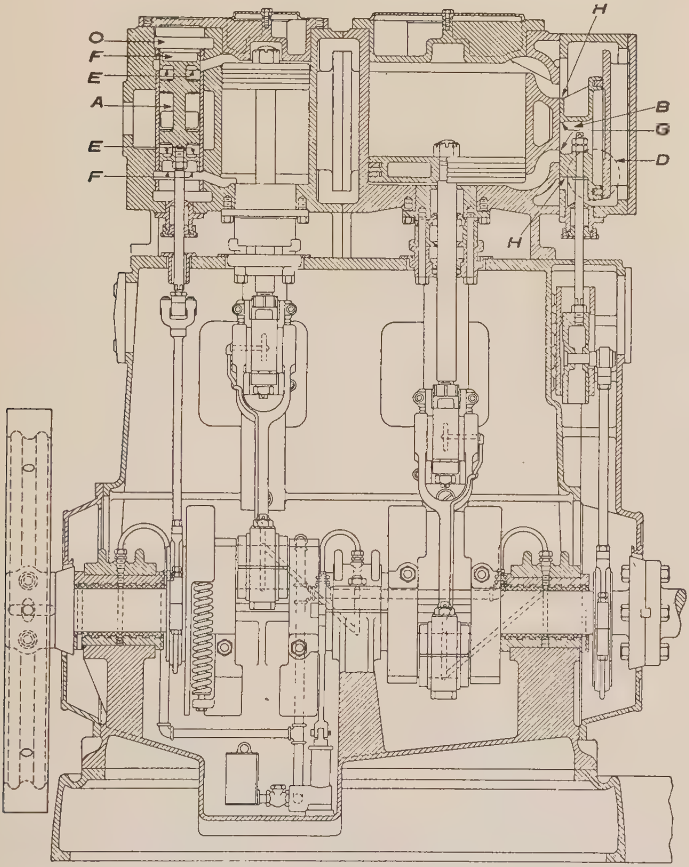


FIG. 147.—Vertical Section of Engine. Form H2. Gen. Elec. Co.

Low-Pressure Valve.—This valve is driven by an eccentric fixed on the crank shaft, and, therefore, always gives the same cut off. The inner face of the low-pressure steam chest cover is exactly parallel with the valve seat and upon this surface the circular ring of the low-pressure valve has its bearing. This ring fits a groove in the valve and is held in place by springs and is self-adjusting for steam tightness, thus automatically following up all wear and affording necessary relief in case of water in the cylinder.

Eccentric Rod and Strap.—Fig. 148 shows the high-pressure eccentric rod and strap with forked brasses which are in three pieces.

The low-pressure eccentric rod and strap are of the same general construction with the exception of the brasses which are in two instead of in three pieces.

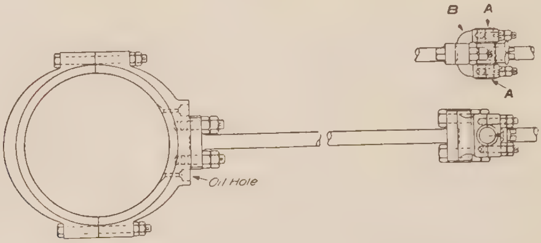


FIG. 148.—Eccentric Rod and Strap.

The bearing caps A are both secured by studs and double nuts. The wear is taken up by filing the cap faces.

The cast-iron guide for the high-pressure valve stem is bolted to the engine column, and is fitted with a composition metal bushing which is pressed into the guide.

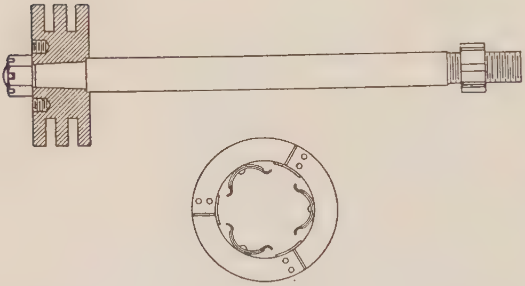


FIG. 149.—Piston, Piston Rod and Piston Packing.

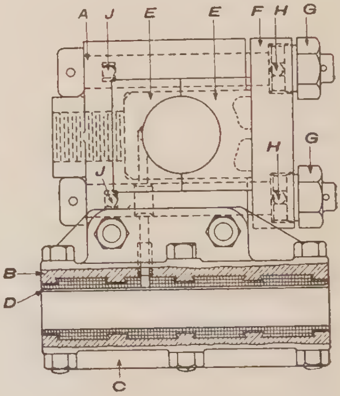


FIG. 150.—Cross Head.

Pistons and Piston Packing.—The high-pressure piston is shown in Fig. 149, and is a cast-iron disk containing two rectangular grooves, which receive the piston packing consisting of three cast-iron arcs, overlapping at the ends and made steam-tight by brass tongues, one of which is riveted to each arc. The packing is held tightly against the cylinder by flat springs as shown. The piston fits on a taper and against a shoulder on the piston rod and is secured by a nut on its upper side. The outer face of this nut contains radial grooves, one of which engages a split pin which prevents the nut from unscrewing.

The low-pressure piston is also of cast iron, the general construction being the same as that for the high pressure, excepting that the packing is in four instead of in three sections, and that the piston is cored instead of being solid.

Piston Rod.—The piston rod (Fig. 149) is of nickel steel, and the diameter of both the high- and low-pressure rods is 2¼ inches. Each rod is threaded at the lower end which screws into the cross head and is locked by a spanner jam nut.

Cross Head.—The construction of the cross head is shown in Fig. 150. The body A is a mild steel forging. The cross-head shoe B is of composition metal, babbitted, and has a very liberal wearing surface so that the wear at this point will be very slight. The cross-head shoe is fastened to the cross head by two 1-inch bolts and is held against the guide bar by the clamp C which is connected to the shoe by six through bolts, the proper distance between the shoe and clamps being maintained by adjustable liners D.

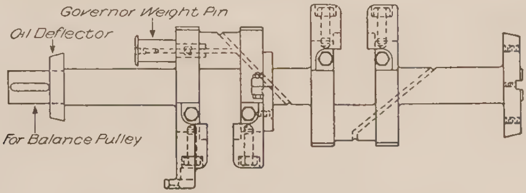


Fig. 151.—Crank Shaft and Coupling.

The cross head is slotted to receive the wrist-pin bearing E which is made of gun metal, and is held in place by cap F and two bolts secured by lock nuts G. The upper part of each nut is turned circular, and fits in a recess in the cap. Set screws H prevent the nuts from turning, and set screws J prevent the turning of the bolts.

Wear may be taken up by filing the edges of the brasses, and on account of the system of oiling which is used in this engine, it is important that these edges should always be together. The bearing should be so adjusted that when the brasses are hard together the wrist pin will move freely but without any play. Oil reaches the bearing from the oil pipe, passing up the side of the connecting rod; from this bearing it is further forced to the guide.

Crank Shaft and Coupling.—The crank shaft and coupling (Fig. 151) for transmitting the power to the generator, are made in one solid piece of forged steel with the crank pins machined out.

Cast-iron counterbalance weights are fastened to each crank opposite the crank pin, to balance the moving parts. Each weight is held by two bolts, one a cap bolt with the head sunk in the weight, the other a through bolt passing through the crank and secured by a nut.

One of these weights acts as a support for the adjusting screw of the governor spring.

One end of the shaft receives the fly-wheel and the opposite end holds part of the coupling.

A radial key, 1-inch square, for transmitting the power, is secured to the face of the coupling.

The shaft has a diameter of 5 inches at the bearings and $4\frac{1}{2}$ inches at the fly-wheel end.

Throttle Valve.—Fig. 152 illustrates the throttle valve furnished with each engine. It is of the Lunkenheimer, regrinding type, and is $3\frac{1}{2}$ inches in diameter. The valve is fitted with a by-pass integral with the body. The valve stem is carried outside of the valve through the yoke, and a bolt and gland stuffing box is used.

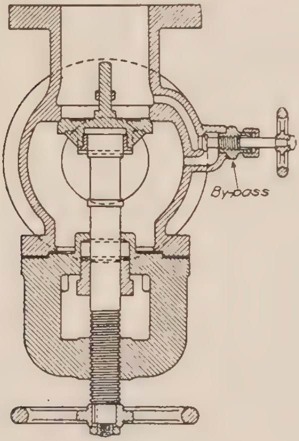


FIG. 152.—Throttle Valve.

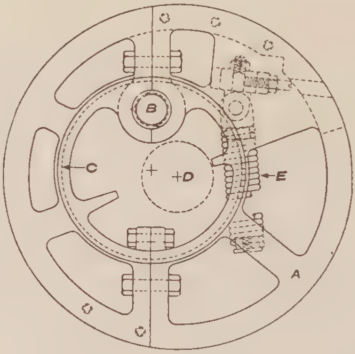


FIG. 153.—Governor.

Governor.—The governor (Fig. 153), of the "Rites" design, consists of a single fly weight A in halves which are securely bolted together and pivoted at B to the governor weight pin which is driven into the crank and secured by a set screw as shown in the illustration of the crank shaft. The fly weight is supplied with a loose brass bushing which provides a double bearing surface. The pin and bushing communicate with the lubricating system and are, therefore, always under an oil pressure which reduces to a minimum the danger of sticking or binding.

The operation of the governor is as follows:

The eccentric rod and strap (Fig. 148) which transmit motion from the governor to the high-pressure valve are connected to the eccentric C forming a part of the weight casting. It is therefore evident that the length of the valve stroke depends upon the distance of the center of the eccentric C from the center of the shaft D.

The amount of steam admitted to the cylinder varies directly as the distance between the centers of C and D; that is, the less the distance the less the amount of steam admitted, and vice versa.

Suppose the speed of the engine to increase; the weight A is immediately drawn out by centrifugal force, thus decreasing the distance of the center of C from the center of D and reducing the amount of steam admitted to the cylinder. Should the speed of the engine approach a dangerous point, the distance of D from the center of C will be diminished until the minimum distance is reached, when the steam is entirely cut off from the cylinder.

The motion of the fly weight is opposed by the spring E which is attached to a bracket cast with the crank-shaft counterbalance. By increasing or decreasing the tension of the spring, the speed may be raised or lowered. The same effect will be produced by moving the spring in the slot of the weight—moving it away from the fulcrum increases the speed and towards the center produces the opposite effect.

Unstable regulation is due, principally, to too close an adjustment of speed and may be avoided by moving the spring attachment away from the fulcrum.

The governor should occasionally be taken apart and cleaned, and care should be taken to see that the oil hole leading to the governor weight pin and bushing is kept free from all foreign substance. This is best accomplished by never allowing any waste or dirt to enter the inside of the column and thus find its way to the different bearings.

Lubrication.—The lubricant is carried under pressure to the various parts of the engine by the mechanism shown in Fig. 154. The base of the engine forms an oil tank. The small oil pump shown draws oil from this tank and forces it to grooves in the main bearings. Drilled holes in the shaft connect these grooves with the crank pins, and the oil is further forced to wrist pins and valve gear through pipes on the side of the connecting rods.

Indicator Motion.—When it is desired to indicate the engine, a small cover must be removed from the front of the column, exposing a slot over which a bracket containing a bearing pin for the levers is attached. Each cylinder has its own indicator motion consisting of a stud screwed into the wrist pin of the connecting rod for driving the motion, which connects through a link to a lever pivoted to the bracket covering the slot in the column. The motion for the indicator is taken from a cord pin on this lever.

Starting the Engine.—Before steam is admitted to the cylinders care must be taken to see that the valves move freely. This may be done by turning the balance pulley by hand. As the expansion of the valves is much more rapid than that of the cylinders, the cylinders should be allowed to attain their proper temperature before full pressure is applied. A by-pass valve, integral with the body of the throttle valve (see Fig. 152), is used for the purpose of heating the engine before starting. The drain valve from the steam chest, together with all the cylinder-drain valves, should be kept open until all condensed water has escaped.

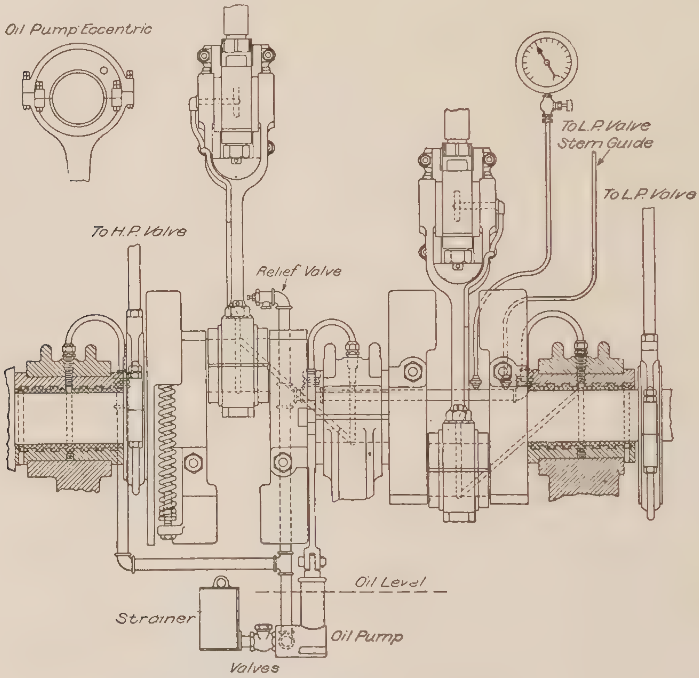

Oil Pump Eccentric
To L.P. Valve Stem Guide
To L.P. Valve
To H.P. Valve
Relief Valve
Oil Level
Strainer
Oil Pump
Valves

FIG. 154.—Lubricating Mechanism.

If water hammering occurs after the engine is started, the cylinder-drain valves should be quickly opened.

The Forbes Engine.

A section of a Forbes engine is shown in Fig. 155. It has several features differing from the one described above, among which are the form of governor and the control of the valve by the governor.

The governor controls the *low-pressure* valve in the Forbes engine and not the high-pressure as in the types of the General Electric Company.

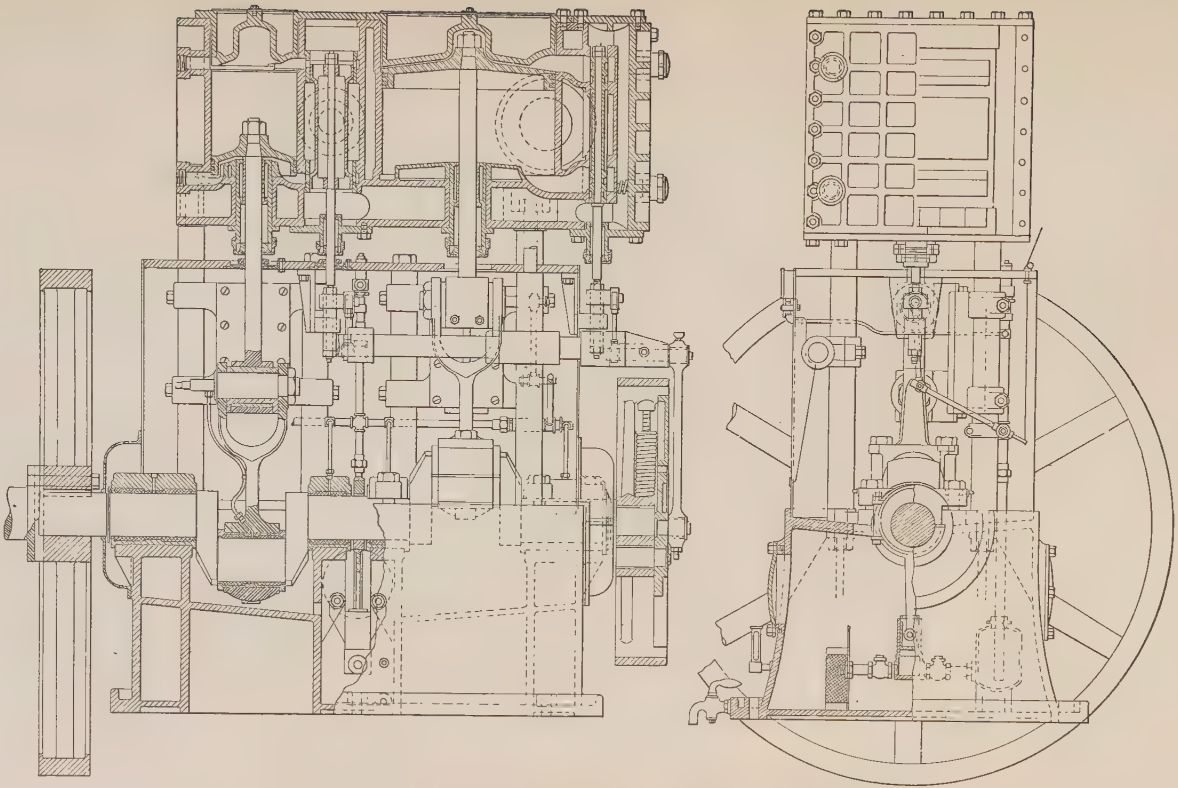


FIG. 155.—Cross-Section W. D. Forbes & Company Engine, 100 kw.

Governor.—There are two types of governor used with the Forbes engine, both constructed on the Rites design.

The weight embraces the greater part of a circle and is attached to a cross arm pivoted as shown in Fig. 155. The spring controls the centrifugal motion of the weight in the usual way. The fulcrum of the spring is adjustable in a slot. The action and adjustments are the same as for other governors built on the Rites design.

The type used with smaller engine designs is shown in Fig. 156. It is a modification of the Corliss type of the Rites design. The governor support is an iron casting keyed to the shaft. At one side of the shaft is an extension which is bushed to form the bearing for a stud extending from the governor weight, and on the other side is an extension which forms the outer point of attachment of the governor spring. The governor weight is a cam-shaped iron casting. The parts of the wheel face between the arms (or spokes) are arched out to reduce shrinkage strains, and to reduce, by a multiplied fluttering, the optical effect of the governor's eccentric rotation. To one of the six arms is attached a stud which forms the inner point of attachment of the governor spring. The eccentric pin is of machine steel and extends outwardly from the hub of the governor weight. The governor weight-retaining plate is secured to two extensions of one of the governor arms and engages with a projection at the governor support to keep the governor in position longitudinally on the stud. When any "sticking" occurs with this type of governor, it will usually be found that the cap nut which secures the weight is set up too tightly.

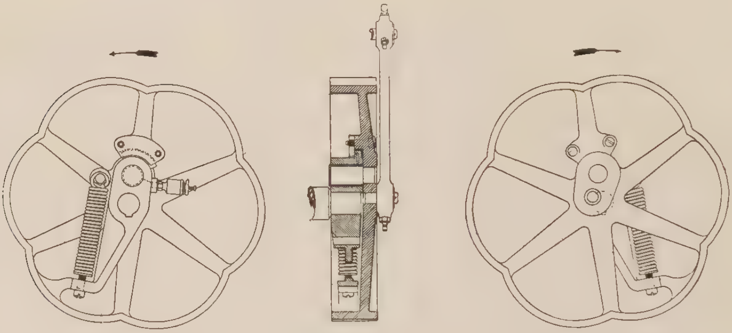


FIG. 156.—Governor for 24 kw. and Below.

The B. F. Sturtevant Engine.

A cross-sectional view of one of the larger engines of this make is shown in Fig. 157.

It resembles in its general features the engine built under the same specifications by the General Electric Company. The **governor** is of the Rites "dumb-bell" type and is mounted on the outside, and inside the fly wheel. The governor controls the high-pressure valve; and the high-pressure eccentric is mounted on a pin extending through the fly and governor wheel. As the weight flies out under the action of the centrifugal force, the eccentric is moved and the travel of the valve is shortened.

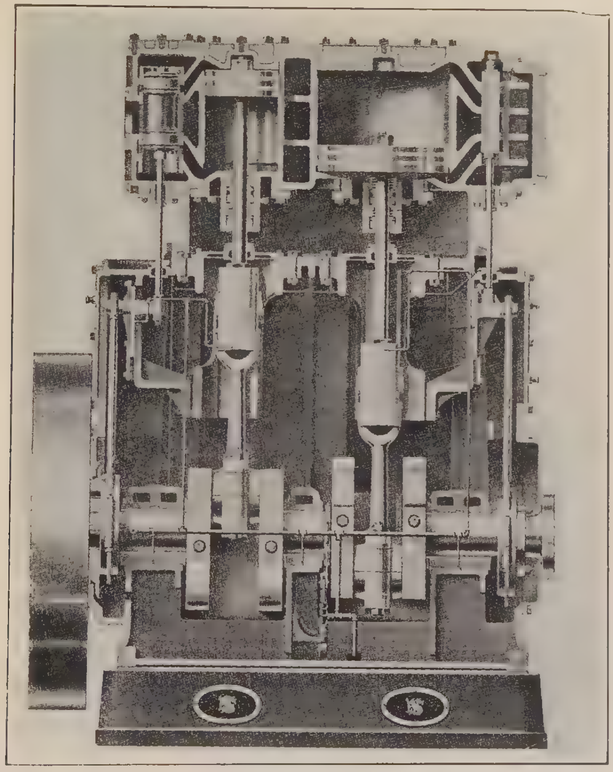


FIG. 157.—B. F. Sturtevant Company's Engine, 100 kw.

TURBINE-DRIVEN GENERATING SETS.

On all the later ships the generators are driven by steam turbines. No attempt will be made to discuss the theory of the turbine, but a short description of some of the turbines now used will be given.

Direct-Connected 300 kw. Turbo-Generator for Battleships.

These generating sets are manufactured by the General Electric Company and the following description is compiled from data furnished by that firm.

General Description.—These sets are rated as **type CC, 6-pole, 300 kw., 1500 R. P. M., 125 volts.** A general outline and sectional view is shown in Fig. 158. They consist of horizontal type Curtis steam turbines, with mechanically operated valves, direct connected to General Electric direct-current generators. The units have two bearings, the turbine wheels being overhung. The turbines are designed to operate at 200 pounds normal steam-pressure gauge and 28″ of vacuum. The turbine will, however, carry its full-rated load when operating non-condensing with normal steam pressure, or with steam pressure 20 per cent below normal with 28″ of vacuum.

The normal speed of the machine is 1500 R. P. M. The turbines are of the two-stage type, *i. e.,* the steam has two successive stages of expansion. This is accomplished by dividing the casing by means of a diaphragm into two compartments, each compartment containing a separate set of wheels mounted on a common shaft. The diaphragm is fitted against a flange of the wheel casing and held in place by the second-stage intermediate ring. Each set of wheels has three rows of buckets on its periphery. Between each two rows of revolving buckets there is a row of intermediate stationary buckets, bolted to the wheel casing in the case of the first stage, and to the intermediate ring in the case of the second stage.

Flow of Steam.—The steam from the steam pipe passes into the valve chest and through the controlling valves to the first-stage nozzles. Up to this point it remains at practically the boiler pressure. As it flows through the nozzles, which are expanding, its velocity becomes very high, while the pressure falls correspondingly. At this high velocity it strikes the first row of buckets on the first-stage wheel, where its direction of flow is changed by the curved buckets and its velocity partially absorbed. It then flows through the intermediate stationary buckets where its direction is again changed and strikes the second row of buckets on the wheel. This is repeated on the second row of stationary blades and on the third row of wheel buckets. The steam then emerges at a very low velocity and at the pressure of the first stage. It then passes through a similar cycle in the second stage, flowing through the second-stage nozzles, wheel buckets and stationary blades.

The following table shows the approximate pressures in the two stages when the machine is operating at 200 pounds pressure (gauge):

Load.	Vacuum.	Steam Chest.	First-Stage Shell.	Second-Stage Shell.
300 kw.	28″	200 lbs.	13.9 lbs.	28″

These pressures vary from the above under different conditions of operation, increasing with higher steam pressures and poorer vacuum, and decreasing with lower steam pressures and better vacuum.

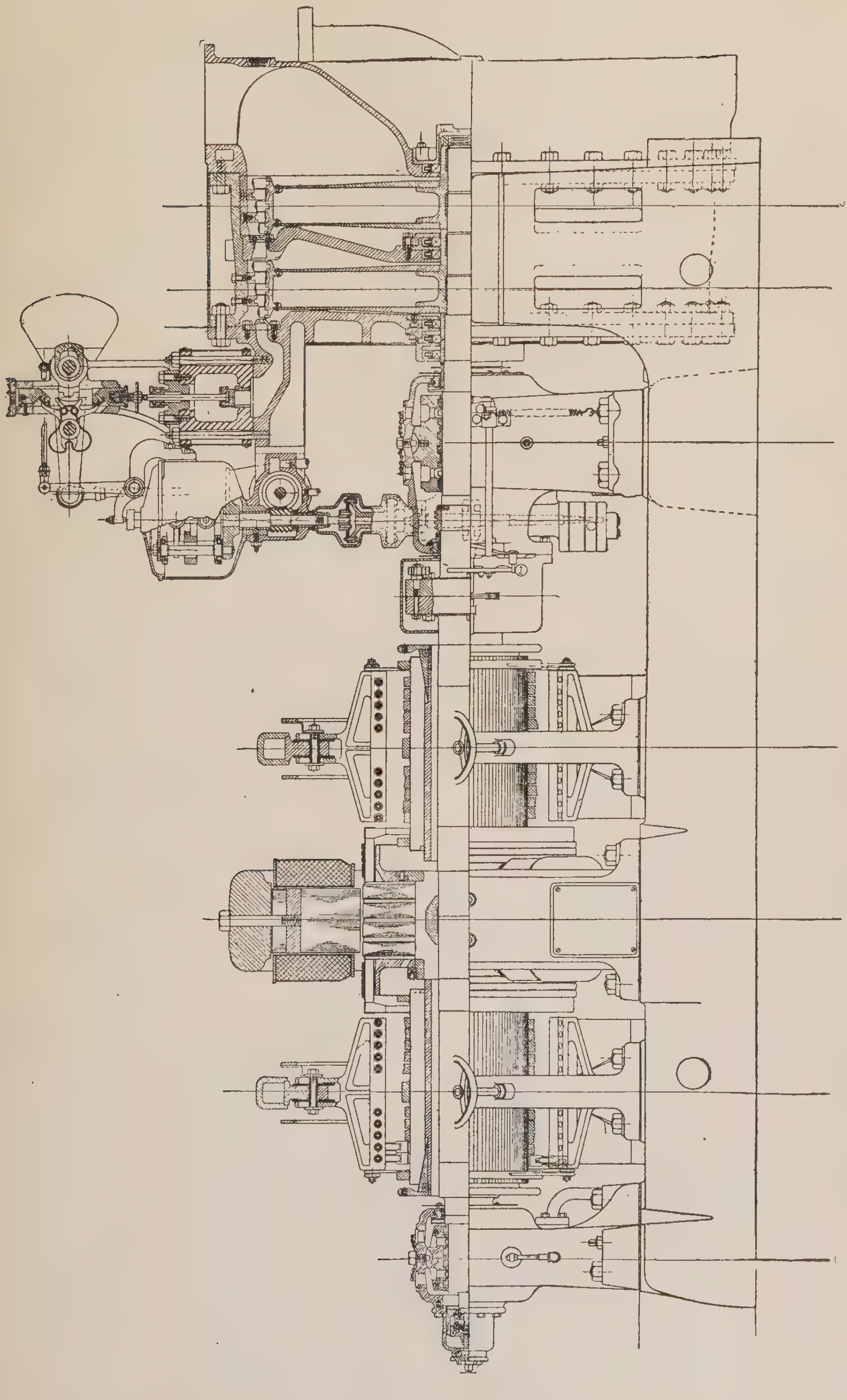


FIG. 158.—Type CC, Six-Pole, 300 kw., 1500 R. P. M., 125-Volt Condensing Curtis Steam Turbine.

Shaft Coupling.—In order that the armature may be removed without disassembling the turbine, the shaft is divided just inboard of the main bearing, and provided with a rigid flanged coupling. The flanges are forged integral with the shafts, are accurately faced and rabbeted, the two shafts being held together and located in position by four taper-ground bolts fitted to reamed holes, and two straight bolts.

Bearings.—The main-shaft bearings are in halves and are cooled by means of water-cooling coils embodied in the babbitt of the lower half of the linings.

A babbitting mandrel is furnished with each installation and it should be borne in mind that bearings in which the surface speed is high require special care in fitting and grooving. The main bearing lining should have a diameter .010″ larger than the diameter of the journal; the bearing at the generator end should have a diameter .007″ larger than the journal. Special care should be exercised to see that no sharp edges are left on the oil grooves and that the babbitt is tight in the shell.

Lubrication.—The main bearings, as well as the governor drive gears, thrust and shaft bearings, are force-feed lubricated from a gear pump located at the lower end of the governor drive shaft. This pump draws its supply from an oil reservoir located in the lower portion of the main bearing pedestal, and to which the overflows are returned. The system is closed and the oil is cooled as it circulates through the two main linings, which are equipped with cooling coils. Approximately 25 gallons of oil are required to fill the system on starting. The reservoirs should be filled to the level indicated by the scratch marks on the gauge glasses and in no case above, as foaming and overflow will result. A light mineral oil, with high flashing point, should be used; oils which form a sediment or gum in the oil chambers must absolutely be avoided.

The reservoir may be filled from the peep holes in the top of the main bearing, and the oil should be strained as it is put in. The system is provided with a strainer, between the reservoir and the pump, which can be cleaned without shutting down the machine.

A gauge for registering the pressure is provided. A relief valve is furnished for adjusting the pressure by by-passing a certain amount of oil from the pressure side of the reservoir. The pressure should never exceed 10 to 12 pounds, and under ordinary operating conditions 3 to 4 pounds is sufficient. Gate valves, with small holes drilled through the seats, are supplied in the feed pipes to generator end bearing lining and also to the governor drive, in order that the supply can be throttled, but can at no time be totally shut off.

Speed Control.—The governor is adjusted to regulate the speed of the turbine when operating under normal conditions within 2 per cent from no load to full load, thus the no-load speed may be 2 per cent above normal,

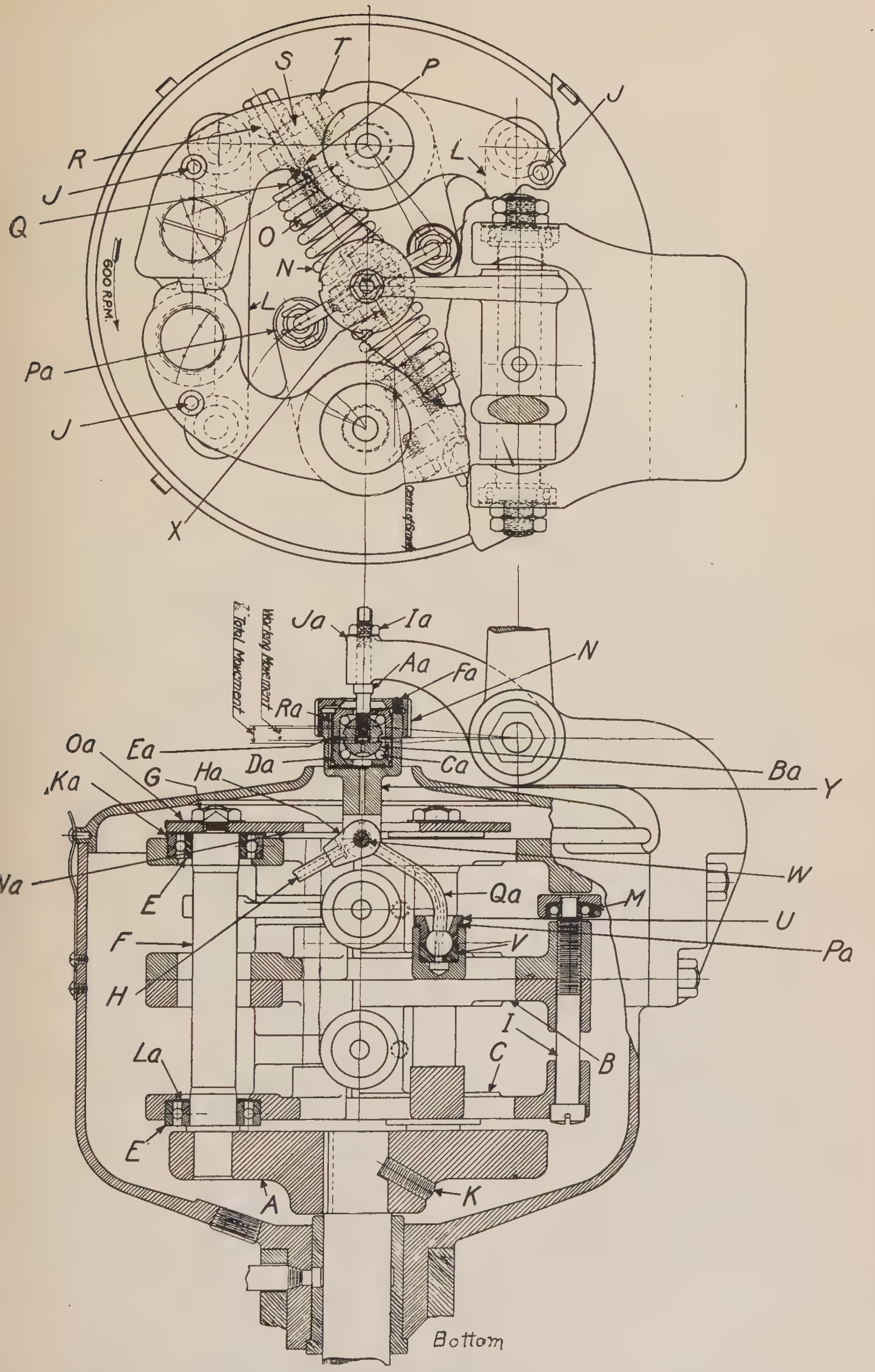

S
T
P
J
R
L
J
Q
O
N
600 R.P.M.
L
Pa
J
X
Centre of Grav
Ja
Ia
Aa
Fa
N
Ra
Working Movement
½ Total Movement
Oa
Ea
Da
Ca
Ba
Ka
G
Ha
Y
Na
E
W
Qa
M
U
Pa
F
V
H
I
B
La
C
E
A
K
Bottom

FIG. 159.—Outline of Governor for Two-Stage, 300 kw., 1500 R. P. M., Curtis Steam Turbine.

or 1530 R. P. M. under 200 pounds steam pressure and 28″ of vacuum. With 300 kw. load on the generator the speed will be controlled by the third or fourth valve, *i. e.*, approximately three valves are required to carry the normal load. When the steam pressure is low or the turbine is operating non-condensing or overloaded the total range of speed to open all six valves is 4 per cent, or from 1530 R. P. M., at no load to 1470 R. P. M. under the maximum condition.

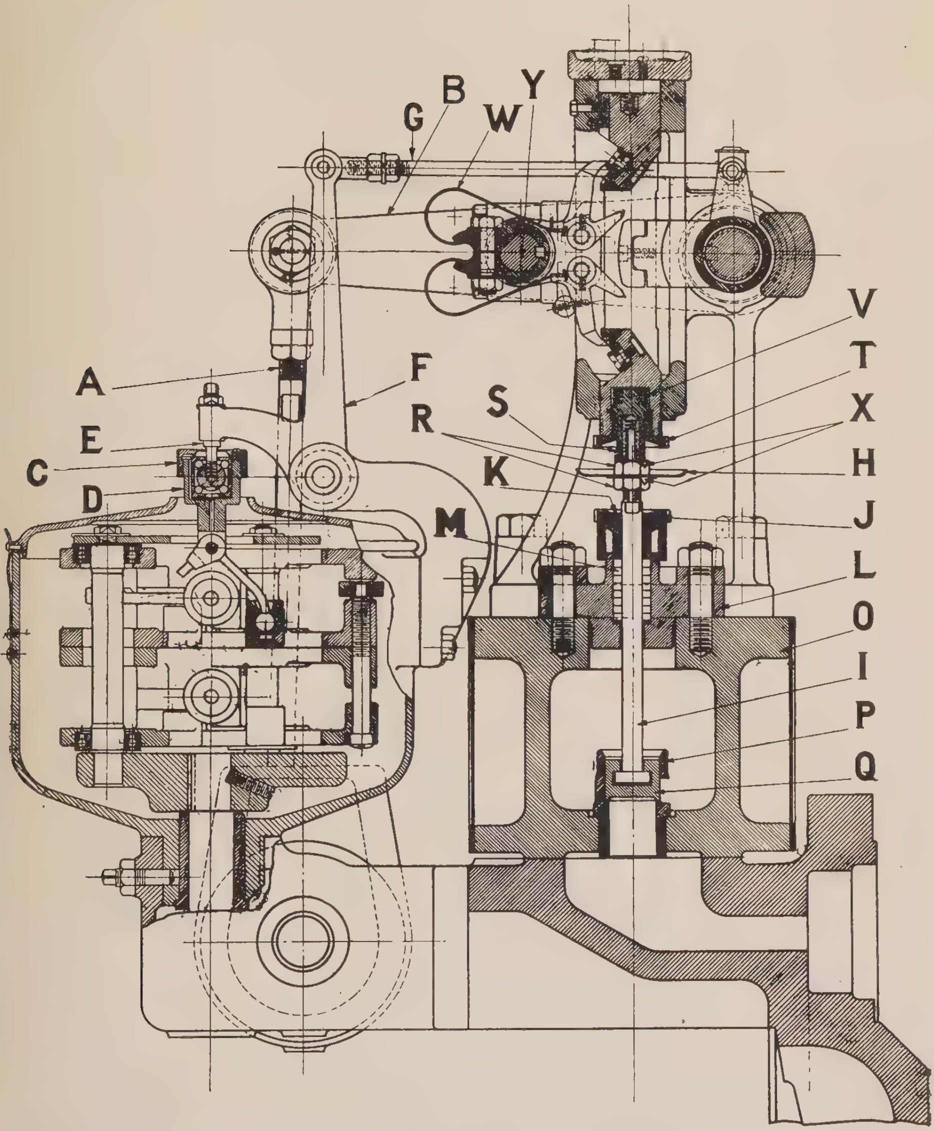
Speed is controlled by the admission of steam to the first-stage nozzles. Each of the six valves controls two nozzles, the valves being opened and closed successively by the governor to regulate the speed.

Valve Gear and Governor.—The valve mechanism is of the cross-head mechanical type, consisting of six valve units, operated by an oscillating steam lever, driven from the main turbine shaft through a double-reduction worm gear, and controlled by an inertia governor mounted on the primary gear shaft. The speed of this shaft is 600 R. P. M. The secondary shaft, which drives the valve gear through a crank, is driven from the primary or governor shaft. Thus, if the normal operating speed of the turbine is 1500 R. P. M., and of the governor 600 R. P. M., the oscillations of the valve gear are 120 per minute.

The governor, see Fig. 159, consists of two weights pivoted on ball bearings. The movement of these weights, due to centrifugal force, is resisted by the helical tension springs, which connect the two weights through knife-edge supports. In addition, the weights are so disposed that their inertia, on changes of speed, acts in a direction to aid the effect of centrifugal force, thereby increasing the sensitiveness of the governor. The motion is transmitted to the valve gear through inverted Y-shaped links, ball bearing and bell crank, all of which are clearly shown in the figure.

The weights and springs should not be altered unless it is found that the adjustment has changed; this can then be remedied by changing the tension spring and adjusting weights.

Valve Gear.—The valve gear is operated by the drive rod A, Fig. 160, which causes the steam lever B and its extension Y to oscillate. On the extension Y are mounted six pairs of pawls: A, Fig. 161 (opening) and D (closing), which operate the valves; a spring W, Fig. 160, is provided, which engages the pawl at F, Fig. 161, causing them to drop into latch blocks of the cross head and to operate the valve when the shield plate E is moved from under the heel G of the pawl by the governor. These springs must be strong enough to perform this function positively, and if, for any reason, they become weakened, they should be replaced by new ones.


G
B
Y
W
V
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X
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S
R
E
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C
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Q

FIG. 160.—Outline of Mechanical Valve Gear for Two-Stage, 300 kw., 1500 R. P. M., Curtis Steam Turbine.

Emergency Governor.—Since any steam turbine can accelerate at a very rapid rate, and since increase of speed may not be easily perceptible, it is very important that all turbines be equipped with a simple speed-limiting device, which will operate in case the regular governing device should fail. Fig. 162 shows the device used for this purpose, consisting of two "clock springs," A, set up under tension against the pin B. The springs are carried on opposite sides of a disc, which is keyed to the shaft. The tension of the springs against the pins is such that at 8 per cent above normal speed the centrifugal effort overcomes the spring effect and the ends move out and away from the pins, tripping the trigger C and releasing the latch which controls the tension spring D. This spring, assisted by the hammer-blow effect due to lost motion in the connection at the end of the reach rod, knocks

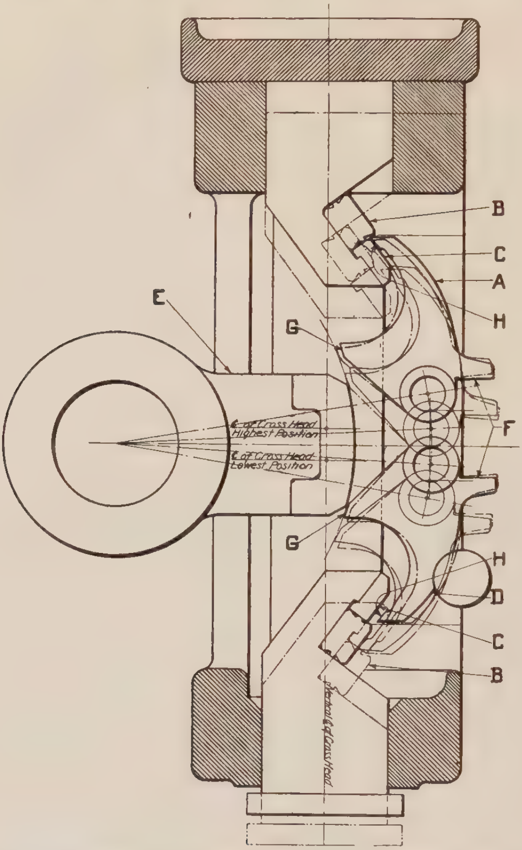


FIG. 161.—Diagram of Valve Gear for Two-Stage, 300 kw., 1500 R. P. M., Curtis Steam Turbine.

out the hook on which the valve and its spindle rest, allowing the whole movable element of the throttle valve to drop and seat the valve. The mechanism of this emergency stop should be thoroughly understood by everybody who has to do with the operation of the turbine. It should be frequently inspected and should be operated at regular intervals so as to guard against the possibility of deterioration or variation of adjustment. No turbine should be kept in service unless it is known that this device is in reliable condition.

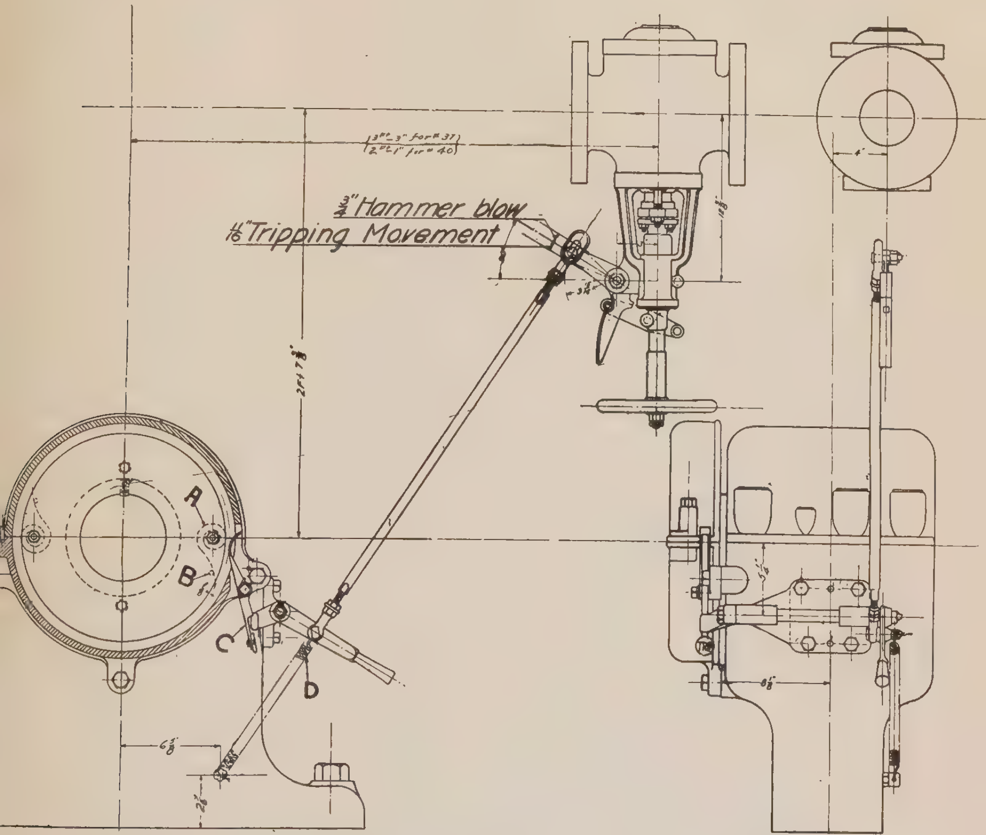


FIG. 162.—Emergency Tripping Device for 300 kw., Steam Turbine.

Back-Pressure Emergency Tripping Device.—As an extra precaution against accident from back pressure a special device is provided which will trip the emergency valve and shut down the machine in case the pressure in the exhaust stage becomes excessive.

This tripping device consists of a thin phosphor bronze diaphragm enclosed in a casing, which is connected by piping to a pop valve placed in the exhaust casing of the turbine. This pop valve is set to operate at approximately 10 pounds gauge, the springs having about 4 pounds initial compression. This gives a pressure of approximately 6 pounds on the diaphragm.

The action of this device is as follows: The pressure increasing in the exhaust stage to 10 pounds causes the pop valve to open, admitting steam to the pipe line leading to the diaphragm. This causes the diaphragm to press outward against the tripping lever, which is so adjusted that when the emergency tripping device is set there is 1/32 of an inch clearance between the pin in the end of the lever and the emergency trigger. The movement of this lever against the emergency trigger releases the latch of the throttle valve, shutting down the machine.

The pop valve operating this device is equipped with a small vent pipe and care should be taken that this opening never becomes clogged.

The turbine should be shut down at least once a week by means of this automatic device to be sure that it is in operating condition. This can best be done by running the machine non-condensing and weighting the relief valve, or by throttling the outlet by hand until sufficient back pressure to trip the device is obtained.

In making this test care should always be taken to see that a properly calibrated gauge is placed in the exhaust stage of the turbine to insure against excessive pressure in the casing.

In addition to the automatic device a pop or sentinel valve, set at 12 pounds, is installed in the exhaust stage of the turbine. If, for any reason, this valve operates, it should be considered as an indication that the automatic device has not operated and the emergency valve should be tripped by hand, shutting down the turbine.

300 kw. Geared Turbo-Generator for Battleships.

On some of the latest ships the turbines drive the generators through gearing, the turbines making 6000 R. P. M. and the generator 900 R. P. M.

The one here described is a 300 kw. unit, manufactured by the Westinghouse Company. (See Fig. 163 and Fig. 46.)

The turbine is of the combination type, consisting of an impulse element and a reaction or Parsons element. Steam is admitted through a steam strainer and hand-operated throttle valve which latter is also automatically operated by an automatic tripping device, which in turn is operated through linkage from the automatic safety-stop governor located on the end of turbine spindle. The automatic safety-stop governor consists of a weight which is held in place by a spring until the turbine overspeeds and reaches a speed

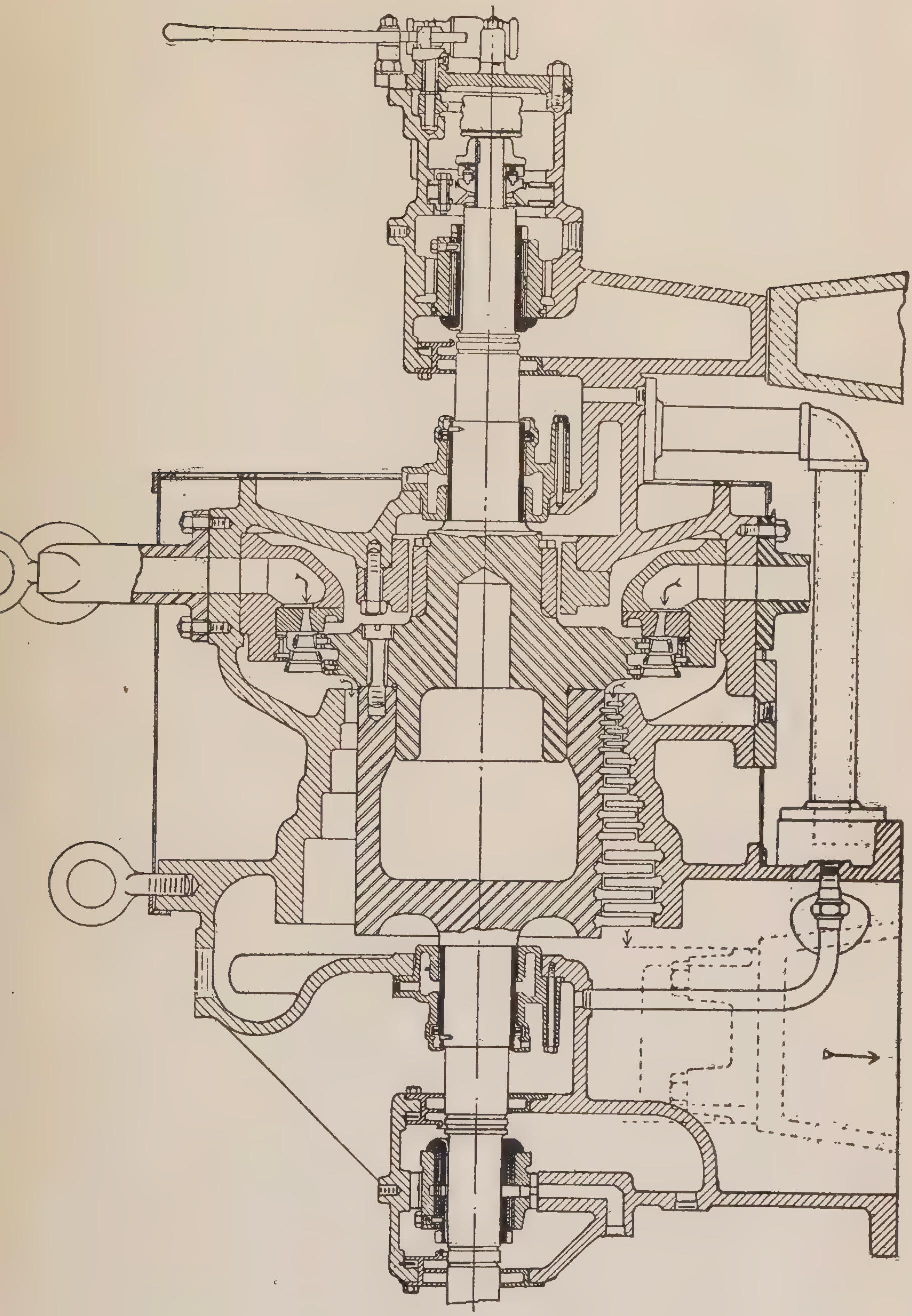


FIG. 163.—Westinghouse Geared Turbine.

about 10 per cent above normal. The centrifugal force on the weight then overbalances the tension of the retaining spring and the weight flies out, operating the tripping device connected with the throttle valve immediately shutting off the steam supply to the turbine.

Two **admission valves**, a primary and a secondary, both under control of the governor, admit steam to the turbine as required. The primary valve admits steam to the primary nozzles for all loads up to and including normal full load, and for overloads passes the additional steam to the secondary valve, which admits this additional steam to the secondary nozzles. Both primary valve and secondary are double-seated, balanced poppet valves.

The **primary** and **secondary nozzles** are mounted in separate chambers bolted to the inside of the cylinder, with pipe connections to the respective valves in the steam chest. In both primary and secondary nozzles, steam is expanded from the inlet pressure to approximately atmospheric pressure, when operating condensing, and then impinges on a row of shrouded blades in the turbine rotor, and after passing through a first row of rotating blades, is received by a stationary row which reverses the direction of flow and redirects the steam into a second row of rotating blades which utilizes the remaining energy in the steam.

The **impulse blades** are made of nickel iron, shrouded at the ends, and are pinned in place in suitable grooves.

After passing through the impulse element, the steam enters the reaction or Parsons element, which consists of several pressure stages comprising rows of stationary and rotating blades. Here the steam is gradually expanded to the exhaust pressure.

The **Parsons blades** are made of drawn bronze and are secured in dovetailed grooves. A packing piece or spacer is placed between each two blades in a groove. Each of the blades has a projection on the toe, turned up on the end of the blade which fits under the packing piece. The blades and packing pieces are driven up tight and then the packing pieces are caulked into place. The ends of the blades are braced with lashing wire to prevent vibration.

A **supplementary connection** is taken out of the steam inlet to the primary nozzles, and by means of a hand-operated valve, steam is admitted to a supplementary group of nozzles, acting on the impulse blades in the same manner as the primary and secondary nozzles, but at another portion of the circumference. This supplementary nozzle permits the turbine to carry 270 kw. with 200 pounds inlet steam pressure and five pounds back pressure in the exhaust.

The **rotor** is made in two sections bolted together, one being a tight pressed fit on the other. The turbine cylinder consists of a lower half and a removable upper half or cover. In the cylinder at the opposite end from the gear and generator, a labyrinth packing is placed so as to prevent steam at the Parsons blading inlet pressure leaking to the chamber formed just inside the glands which has the same pressure as at the end of the Parsons blading or exhaust. This chamber is connected by means of a pipe to the exhaust, so as to maintain the same pressure on either side of the rotor, and at the inside of the glands.

The **rotor-packing glands** are of the water-sealed type, with auxiliary glands of packing rings and steam seal to be used in starting up and until the unit has speeded up. All are mounted in a case bolted to the turbine cylinder.

The **water-sealed glands** consist of a runner with side vanes pressed on the turbine rotor and secured with headless set screws. Water is supplied to the chamber surrounding the runner by a rotary pump which maintains a pressure greater than the difference in pressures inside and outside of the turbine cylinder. The gland runner, when revolving, forces water to the outer circumference and seals the glands from any air or steam leaks.

The **steam-sealed gland** consists of two nests of four rings each, pressed lightly against the rotor by means of phosphor bronze springs. A steam connection is provided to the space between each two nests of rings so that when starting condensing, steam may be admitted to prevent any air leakage into the turbine until the turbine has speeded up sufficiently for the water glands to pack effectively when the steam is to be shut off.

A **rotary-gear water pump**, driven by means of a worm wheel from the gear shaft of the reduction gear, is used to pump the required water to the glands. The pump suction may be taken from the feed water tank or some other source of fresh water supply. Water containing any sediment that might clog the runners, or that would be objectionable to have leak into the cylinders, should not be used. From the pump, the water is discharged to the glands. A relief valve set at the required pressure is placed in the discharge line, and discharges any surplus water in excess of that required by the glands, back to the source of supply.

An **outlet** with a valve is provided with each gland which permits a circulation of water through the glands when required. After passing through, the gland water may be returned to the source of supply. When operating non-condensing, it is necessary to have sufficient water circulating in the glands to keep the temperature below that of evaporation, but when operating condensing, only enough is required to make up a slight leakage or evaporation at the glands.

The **turbine bearings** are of the tubular type, consisting of a cast-iron shell with cylindrical-turned keys bolted on, and with steel liners under each key for perfectly aligning the rotor. The shell contains the bearing proper, which consists of a bronze sleeve fitting loosely on the shaft and encased in three loose-fitting concentric bronze tubes, all of which are prevented from turning by dowels. The clearance between tubes is filled with films of oil, which allow the shaft to assume its true axis of rotation.

At the end of the rotor, opposite gear and generator, is a **thrust bearing** which takes any end thrust and maintains the longitudinal alignment of the rotor. A flood of oil is maintained through the thrust bearing, which insures thorough lubrication. At the end of the rotor is the before-mentioned automatic safety stop.

The **turbine pinion** is connected to the **gear-pinion** shaft by means of a flexible coupling.

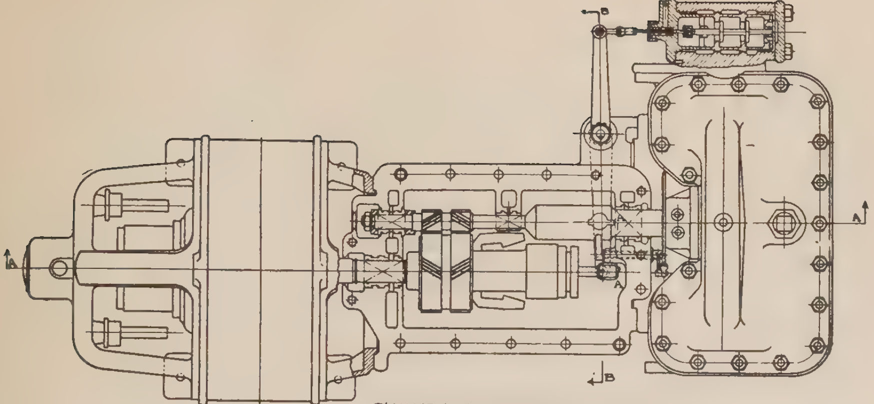
The **governor** is of the fly-ball type with compression spring, adjustable, to which access may be had by removing the small cover on the top of governor casing. The governor weight arms are set on knife edges. The movement of the governor is transmitted through a sliding sleeve and clutch to a lever attached to the poppet-valve stem on the steam chest. The turbine governor is driven by a worm and worm wheel from the end of gear shaft of the reduction gear, and operates at 493 R. P. M. when the turbine is running at 6000 R. P. M.

The **oil pump** consists of two spur gears driven from an extension of the governor spindle, attached with a clamp coupling. It supplies all bearings on the unit with oil. It also supplies the reduction gear under a pressure of about six pounds per square inch. The oil is pumped through an oil cooler on its way to the bearings, and a generous supply is furnished so as to both lubricate freely, and maintain the temperature of the bearings within reasonable limits. After passing through the bearings, the oil spills into reservoirs and is returned by gravity through a strainer to a main reservoir, from which it is taken by the oil pump and used over again. Pressure gauges and sight-flow indicators are placed in the inlet pipe to each bearing. A relief valve is placed in the discharge line from the pump so that the surplus oil supplied by the pump is discharged back to the oil reservoir. This valve is set so as to maintain the oil supply to bearings at about six pounds' pressure.

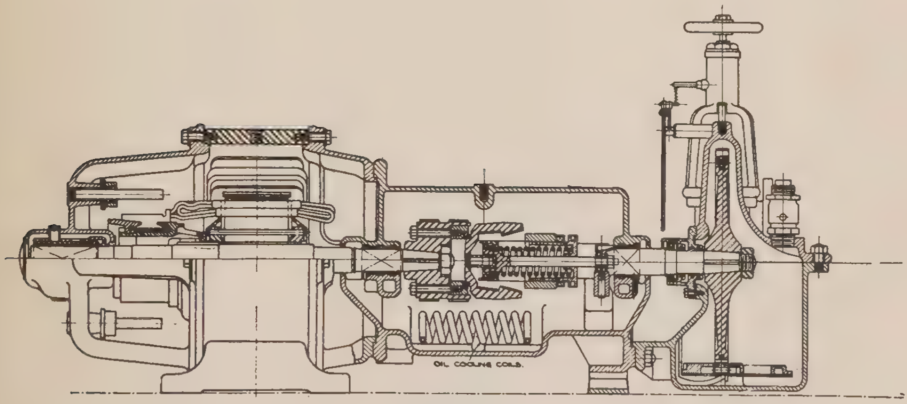
Turbine Used with 25 kw. Generating Sets for Destroyers.

(Figs. 164 and 165; also Fig. 37, page 24.)

Turbine.—The turbine is of the impulse type, operating at 7200 R. P. M. and driving the generator at 1200 R. P. M. through a fixed bearing reduction gear.

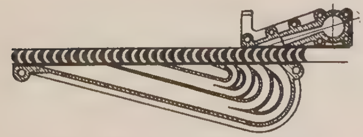


PLAN VIEW WITH GEAR CASE COVER REMOVED

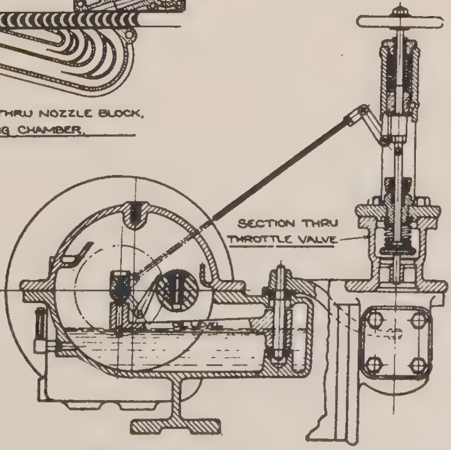

OIL COOLING COILS.

SECTION AAAA

FIG. 164.—25 kw. Turbo-Generator.



DEVELOPED SECTION THRU NOZZLE BLOCK, BLADES AND REVERSING CHAMBER.


SECTION THRU THROTTLE VALVE
OIL LEVEL

SECTION B B

FIG. 165.—25 kw. Turbo-Generator.

Rotor.—The turbine rotor is a steel disc mounted on the end of the reduction shaft, being keyed on a taper fit. Shrouded nickel-iron blades are fitted in a groove in the periphery of the rotor and securely pinned in place.

Steam.—Steam is admitted to the turbine through a hand-operated throttle valve, which is also under control of an automatic stop, and then through a double-seated balance valve under control of governor to a nozzle block, where it is expanded from the inlet pressure to the exhaust pressure. After impinging on and leaving the blades, where only a portion of the energy is absorbed, the steam is received in a reversing chamber which is a non-expanding nozzle, and is directed a second time through the blades in another portion of the circumference and then to the exhaust.

Cylinder.—The cylinder casing is made of cast iron, in halves, and is bolted to the reduction gear case. The upper part, or cover, is removable, giving access to internal parts. Provision is made on the generator frame and reduction gear housing for bolting to the frame of the ship.

Gland, Water Seal.—A water-sealed gland is provided to prevent air or steam leakage where the pinion shaft passes through the cylinder.

Gland, Steam Seal.—A gland is provided to which live steam is admitted forming a steam seal between the gland impeller and the inside of the cylinder. It is used when starting up condensing, or in case the supply to the water-sealed gland is temporarily shut off.

Automatic Safety Stop.—The safety-stop governor is located on the pinion shaft and consists of a weight held in place by a spring until the turbine overspeeds from 7 to 10 per cent above the normal speed. The centrifugal force on the weight then overbalances the tension of the spring. The weight flies out, operating through a linkage tripping device connected with the throttle valve, shutting off the steam supply to the turbine.

Governor.—The governor is of the fly-ball compression spring type, with weight arms mounted on knife edges, and is mounted on the end of the gear shaft. It controls, through levers, the degree of opening of the governor valve as required by the various loads carried. It is enclosed with the gears in the reduction gear housing.

Reduction Gear.—The reduction gears consist of two sets of steel helical gears made right and left so as to balance the end thrust, and are mounted in a cast-iron housing with cover. The gear is keyed on a taper fit on the end of the generator shaft which extends through to the middle of the gear housing. Two thrust collars, adjustable with liners, on the pinion shaft and on either side of the bearing, fix the end alignment of pinions and turbine rotor. This, being set by the builders, needs no further adjustment. The gear and generator rotor are free to float the slight amount of the clearance in the gear teeth. The reduction gear housing is bored to receive pinion and gear bearings which are babbitt-lined, cast-iron shell, horizontally split.

Lubrication.—The reduction gears revolve in a pool of oil in the bottom gear housing for teeth lubrication, and the surplus oil thrown off is collected in the channels in the gear housing, after which it spills back into the reservoir in the bottom. A copper coil for the circulation of cooling water is placed in the reservoir for cooling the oil. The moderate speed generator bearing is lubricated by oil rings.

CHAPTER X.

SWITCHBOARDS AND DISTRIBUTION PANELS.

A **switchboard** receives electric power from one or more sources of supply, and distributes that power to the various circuits supplied from that board.

In the early days a single switchboard sufficed for all purposes. As the size of ships increased, their electrical installations became not only larger but also more complicated, due to the growing use of electric power for a variety of new purposes, and the displacement of other forms of power. The main switchboard was subdivided into a **generator panel** and a number of **distribution panels**; and for very large ships it also became advisable to have **auxiliary distribution panels**, located in parts of the ship near to localities they supply, and themselves supplied by **feeders** from the main switchboard. The above methods of distribution not only effected a saving in copper, but made the installation at the same time less complicated, cheaper, and more efficient.

To effect this the switchboard has heavy leads called **bus bars**, which are the common circuits into which the generators deliver their output, and from which the feeders draw their supply of power. If the bus bars are energized, any circuit desired may be energized merely by closing the switch connecting it to the bus bars.

Generators in the Navy are compound wound. It is the uniform practice to have the series coil on the *negative* side of the line, which necessitates a **common negative** bus bar, and a common **equalizer** bus bar; and one or more **positive** bus bars for lighting, power, search-lights. etc. Switches connect these, as desired, to the various generators, and to the circuits or distribution boards supplied from those bus bars.

On the switchboards are usually mounted a number of instruments, such as voltmeters, ammeters, wattmeters, and ground detectors; and such devices as circuit breakers, control for generator field, search-light rheostat control, and the like, depending on the circumstances of the case and the approved specifications at the time of installation.

Switchboards for Special Purposes.

In addition to the main switchboards and auxiliary panels as above described, certain special switchboards are provided. These are entirely separate from the main switchboards, and will be described, as necessary, in connection with the apparatus they control. These include:

(1) Interior-communication switchboard, with panels for controlling each means of interior communication.

(2) Action cut-out switchboard, with panels for mounting all action cut-out switches required for the interior-communication system.

(3) Fire-control telephone switchboard.

(4) Salvo-signal switchboard.

(5) Battery-charging switchboard.

(6) Range and deflection transfer-switch panel.

(7) Gyro-control panel.

(8) Radio panels.

Early Switchboards.—Some of the early types are obsolete, and will not be described here. They are met with, if at all, only in a few of the older and smaller ships, in which the electrical installation, being small, is readily understood. They do not differ in principle from later types.

Main Switchboards.

Main switchboards may be divided into those for (1) battleships, and (2) other vessels.

Battleships.—Each main switchboard consists of one generator panel, two bus-feeder panels (one for total power and the other for total lighting), and search-light and distribution panels as required for the power and lighting circuits.

Fig. 166 shows the elementary wiring diagram of a main switchboard of a battleship. For the sake of clearness, most of the instrument connections have been omitted. In this plan the switchboard is *seen from the front.* Most drawings of switchboards show the board as seen *from the rear.* In the latter case, the panels necessarily appear in reverse order. The figure should be carefully studied in connection with the following description:

The **generator panel** includes the necessary apparatus for control of the generators, the regulation of their voltage, and the distribution of the load among them. It includes also circuit breakers for the protection of each generator, and selective switches for cutting in any generator on light, or power, or both, or disconnecting it when idle. It includes one equalizer bus bar, one common negative bus bar, and separate positive bus bars for lighting and for power. In the older installations, where no bus-feeder panels are installed, it includes additional positive bus bars for search-lights, forward turret, and after turret. If a main generator is to be used, under Ward-Leonard system, for turret training, or for anchor windlass, there are additional devices for such use. If the generators are 240 volt (Dobrowolsky system), then there are additional neutral and equalizer bus bars.

The **bus-feeder panels** have bus bars which are practically a continuation of the main bus bars of the generator panel. That for total power has the positive power and common negative; that for total lighting the positive lighting and common negative.

The **total power panel** subdivides the power into turret power and miscellaneous power, and (where a ship has two dynamo rooms) has connections so that either turret feeders, or power feeders, or both together, of either switchboard, may be energized from either dynamo room. Interlocking circuit breakers for this purpose are located on the total power panel, with leads to the total power panel in the other dynamo room. The purpose and action of the interlocking circuit breakers will be described later. The turret power and miscellaneous power bus feeders lead to bus bars on the adjacent power distribution panels.

The **total lighting panel**, like the total power panel, has leads, fitted with interlocking circuit breakers, to the total lighting panel in the distant dynamo room. It may be energized from either dynamo room, and supplies the adjacent lighting panels. The total lighting panel usually has the voltmeters, ammeters and wattmeters, not only for total light, but for turret power and for miscellaneous power as well, as there is not room for these on the total power panel.

The **search-light panels** are usually part of the lighting distribution panels. As a rule they derive their power either from the turret power bus bars or from the miscellaneous power bus bars, unless the power circuits are operated at double voltage (Dobrowolsky system), in which case, power for search-lights is taken from the lighting busses.

Double-pole circuit breakers are in the line for each search-light. There is also an ammeter for each search-light, and there are two voltmeters with selective switches, one to indicate the voltage across the light and power bus bars, and the other to indicate the voltage across any search-light arc. There are also search-light rheostat control handles either on or adjacent to the search-light panels. With large lights the rheostat itself, or the larger (and permanent) part of it, is located in an adjacent room.

The **lighting distribution panels** take current from the total lighting panel, and distribute this to the various lighting circuits. Each circuit is fused, the fuses being adjacent to the respective switches.

The **power distribution panels** distribute power from the turret power bus bars to the various turret control panels, and from the miscellaneous power bus bars to the miscellaneous power circuits. Circuit breakers and fuses are installed as required.

Other Vessels.—These conform, as nearly as practicable, to the specifications for battleships, and differ according to the type of ship and size of installation. Torpedo-boat destroyers have one generator panel and one distribution panel. Armored cruisers have installations approximating those of battleships of same date.

General Specifications.—The following are taken from the Navy Department specifications for switchboards, and describe certain features which are of interest:

PANELS.—Non-inflammable, high dielectric strength, and smooth, durable finish.

SWITCHES.—(1) Current density of contacts must not exceed 50 amperes per square inch of *contact surface,* and other current-carrying parts not over 800 amperes per square inch *cross-section.*

(2) Switch handles black except for battle lighting circuits, which are red.

(3) Horizontal switches hinge to the right and throw to the left.

FUSES.—Enclosed type, fuse ratings 150 per cent of the feeder they protect.

BUS BARS.—(1) Hard drawn copper of conductivity at least 95 per cent, designed on a basis of a current density of 1000 amperes per square inch of cross-section.

(2) If for current in excess of 400 amperes, must be made in strips. Strips must be not over ¼-inch thick. If several strips are used, the clearance between strips must be at least equal to thickness of strips.

(3) Generator bus bars and bus feeders are designed on a basis of 33⅓ per cent overload; other bus bars on basis of 75 per cent of rated full load of all apparatus they supply.

NAME PLATES.—Every piece of apparatus has a suitable name plate.

POLARITIES.—Unless otherwise approved, like polarities are similarly disposed on any one board. Facing the front of the board, the upper blades of horizontal switches and the right-hand blades of vertical switches, are all of positive polarity. When a number of circuit breakers appear on a panel, the coils all have the same polarity.

ILLUMINATING FIXTURES.—Installed in front and back of board, supplied with current from several sources, *i. e.,* some direct from generators, and others from light and power busses.

Switchboard Devices.

Before taking up the detailed description of individual types of main switchboards, several typical devices will be described.

Interlocking Circuit Breakers.—These are installed where a ship has two dynamo rooms, located so far apart that the generators in both rooms cannot be simultaneously controlled by the same man. The circuit breakers are of the I. T. E. type, described in Chapter IV, fitted with "locking" and "no-voltage" coils. They are designed to automatically protect the generators in one dynamo room against being thrown in parallel with those in the other dynamo room on the same circuit; or a dead generator against full voltage, in the event of the operator's forgetting to open the circuit breaker when stopping the generator.

The connections for this purpose are as shown in Fig. 167, representing the total lighting panels in the forward and after dynamo rooms, each fitted with interlocking D. P. circuit breakers. In order to illustrate better the interlocking action, circuit breakers A_1B_1 are shown in closed position, and circuit breakers A_2B_2 in open position.

The *locking coils* L_1 and L_2 are connected across the common bus feeders, and when these feeders are energized, the respective circuit breakers, if opened, are locked open by means of the locking-magnet armature; which, being attracted, interposes a mechanical latch that prevents either side of the D. P. circuit breaker from being closed.

The *no-voltage coils* NV_1 and NV_2 are across the supply bus bars in their own dynamo room. If these bus bars become dead, the no-voltage magnet becomes de-energized, its armature is pulled back by a spring, and trips the circuit breaker release, opening both poles.

C_1 and D_1 are automatic switches which open the circuits of the locking coil and no-voltage coils, respectively. C_2 and D_2 are duplicates of C_1 and D_1. The action of closing circuit breaker B_1 opens C_1, as there is no need for this circuit when the circuit breaker is in the closed position. If the locking coil is energized, the mechanical latch prevents the circuit breaker from moving far enough to open its own locking coil.

The action of D_1 in the no-voltage circuit is similar, except that the act of closing the circuit breaker closes the switch D_1, and energizes the no-voltage coil. There is no need of this coil unless the circuit breaker is closed. The circuit breaker can be closed whether the no-voltage coil is energized or not; but will open as soon as the hand is removed, unless the coil is energized. As the no-voltage switch D_1 is closed by the act of closing circuit breaker A_1, it is necessary that circuit breaker A_1 be closed before B_1, or B_1 will not remain closed, or, in other words, that the no-voltage circuit breaker be closed first.

It will thus be seen that, if the + lighting and the common − in each dynamo room are energized, any of the following conditions may be brought about:

(1) Throw S_1 to the right and S_2 to the left; each dynamo room supplies its own total lighting panel separately.

(2) Close A_1B_1 and throw S_1 and S_2 to the right; the forward dynamo room supplies both, and A_2B_2 is locked open.

(3) Close A_1B_1 and throw S_2 to the right (as before), and S_1 to the left; the forward dynamo room supplies both, as before, but both draw power through A_1B_1.

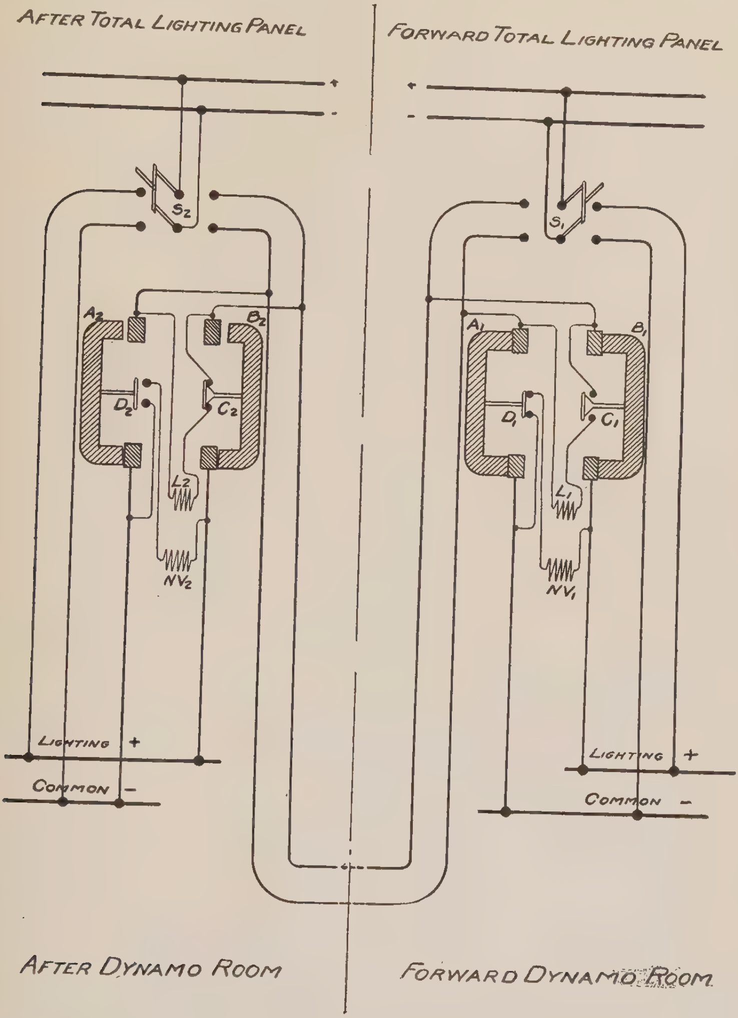

AFTER TOTAL LIGHTING PANEL
FORWARD TOTAL LIGHTING PANEL
+
-
+
-
S2
S1
A2
B2
A1
B1
D2
C2
D1
C1
L2
L1
NV2
NV1
LIGHTING +
COMMON -
LIGHTING +
COMMON -
AFTER DYNAMO ROOM
FORWARD DYNAMO ROOM

FIG. 167.—Interlocking Circuit Breaker, Wiring Diagram.

(4) Similarly both may draw power from the after dynamo room.

Ground Detectors (See Fig. 166).

(a) **Lamp Ground Detectors.**—The theory of these is discussed elsewhere. There are installed usually one lamp detector for light and one for power, on the respective total light and total power panels. There is a switch, in the connection to ground from between the lamps in each set, so that this connection can be broken when testing for grounds with the voltmeter ground detector. Unless this artificial ground connection is broken, the readings on the voltmeter ground detector are without value.

(b) **Voltmeter Ground Detector.**—This is merely an ordinary voltmeter, but graduated with zero in the center of the scale, so that it may be connected to a circuit either way. One leg is permanently grounded, and a selective switch connects the other leg to the bus bar which is to be tested. The name plate attached to the instrument has marked on it the resistance of the voltmeter, for use in calculating the amount of the ground on any circuit.

Selective Switches.—The selective switch shown in Fig. 168 is the latest type of switch used in the service. It has sliding-spring contacts, and is set for any of its various circuits merely by turning the handle until the pointer indicates that circuit on a scale.

Another type formerly used is described in connection with the old standard switchboard and is shown in Fig. 171.

Switchboard Instruments (Fig. 166).

Voltmeters are installed as follows:

One for each generator, connected to the generator terminals, and located on generator panel. It thus gives the voltage of that generator, whether the latter is connected to the bus bars or not.

One calibrating voltmeter, with selective switch, so that it can be put in parallel with either generator voltmeter, or across the lighting or power bus bars, for checking other voltmeters; on generator panel. This voltmeter is also often connected as a ground detector, in addition to the regular ground detector. But it is graduated only one way, the selective switch being arranged to connect it properly from + or − bus bars to the ground.

One with selective switch so that it will give voltage across turret bus bars, miscellaneous power bus bars, or lighting bus bars; on total lighting panel.

One with selective switch to give voltage across forward lighting, forward power, after lighting, or after power bus bars; that is, to the total light and power busses in own dynamo room, and to the respective lighting and power bus feeders from the distant dynamo room; on lighting panel.

One ground detector voltmeter (described under "Ground Detectors"); on lighting panel.

One with selective switch, to indicate voltage across any search-light arc; on search-light panel.

Ammeters on switchboards are not self-contained, but have external low-resistance shunts on the back of the switchboard. These are usually located in the *positive* side of the line. For calibrating the switchboard ammeters, certain of the bus feeders have removable strips, so made as to be readily replaceable by the ship's portable ammeter shunt; the switchboard ammeter and portable ammeter will thus be in series with each other. Ammeters are installed as follows:

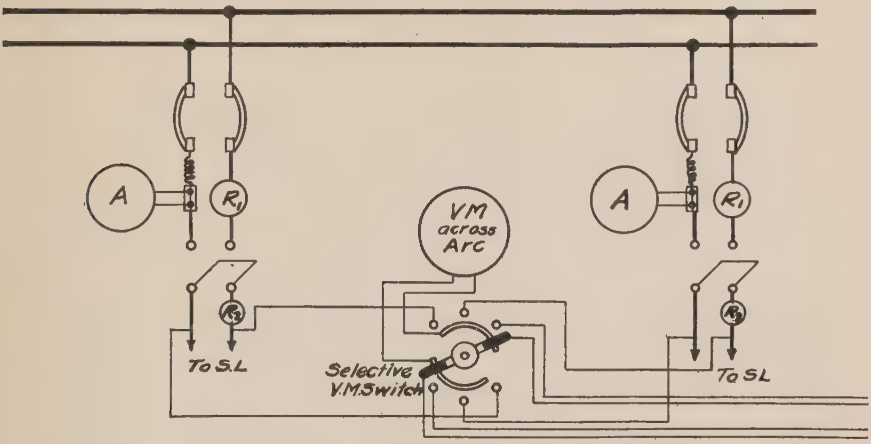
One for each generator, on generator panel.

One for total lighting, on total lighting panel.

One for turret power (search-lights are usually on this circuit); on lighting panel, unless space is available on power panel.

One for miscellaneous power; on lighting panel, unless space is available on power panel.

One for each search-light; on search-light panel.



R_1, variable rheostat located on or near switchboard.
R_2, permanent rheostat located in adjoining room.
FIG. 168.—Search-light Circuits.

Watt-Hour Meters.—These also have been called *integrating wattmeters.* They are of the motor type, and have three connections; namely, two to the two ends of a low-resistance shunt in one side of the line (usually the ammeter shunt), and the third connection to the opposite side of the line. Watt-hour meters are installed as follows:

One for each generator; on generator panel if space is available.

One for total lighting; on lighting panel.

The locations given above for the different instruments are only approximate. Usually there is no space available for instruments on power panel. The locations chosen, in case generator or distribution panels are too crowded for all their instruments, differ somewhat in different installations.

Search-light Circuits.

These circuits are shown in Fig. 168 more in detail.

The search-light rheostats take up so much room, and generate so much heat, that it is not practicable to have them on the switchboard, except for a very small search-light. Accordingly they are often divided into a large permanent, and a small variable, rheostat. The handle of the small variable rheostat, if not on the switchboard, is near it so that the voltmeter may be read while the rheostat is being adjusted.

Old Standard Switchboard.

This switchboard is still met with in many of the older battleships and armored cruisers, and while it does not differ in principle from later types, its arrangement differs considerably.

The one to be described is for a plant of eight generators, in one dynamo room, and designed for use on a ship with two electrically operated turrets, Ward-Leonard system.

The general arrangement is such as to allow any number or combination of generators to run on any circuit or combination of circuits. These circuits are five in number; namely, search-light, lighting, power, forward turret turning and after turret turning. The switchboard has a horizontal positive bus bar for each of these circuits, and a common negative for all.

The negative pole of each machine can be connected by a single-pole switch to the common negative bus bar. Each generator has its own positive bus bar, which is vertical; and where it crosses each of the five horizontal bus bars, there is a single-pole switch. This allows the positive pole of each, any, or all generators to be connected to each, any, or all circuits.

For paralleling generators there are two separate equalizer bus bars, one for lighting and another for power and search-lights (there will be no occasion for paralleling machines on turret-turning circuits). Generators, as desired, are connected to these equalizer bus bars by removable blade plug switches.

When a generator is used to operate the turret-turning motors, the series field is short circuited through a special German silver shunt, in addition to the shunt used on the generator itself. This is accomplished by single-pole single-throw switches at the base of board, one switch to each machine.

Referring to Fig. 170 the generator panel is arranged in eight vertical sections, each section containing all the apparatus necessary for the operation of its own generator. Starting at the top we have a single-pole automatic circuit breaker, connected in the positive leg of the generator; then the ammeter shunt (on back of board); then the ammeter; then the wheel for operating the field rheostat. Next comes the plug receptacle for connecting to voltmeters, and then the field-control switches, three pairs of single-pole single-throw switches (description of last two devices follows later). Next come five single-pole single-throw positive generator switches by means of

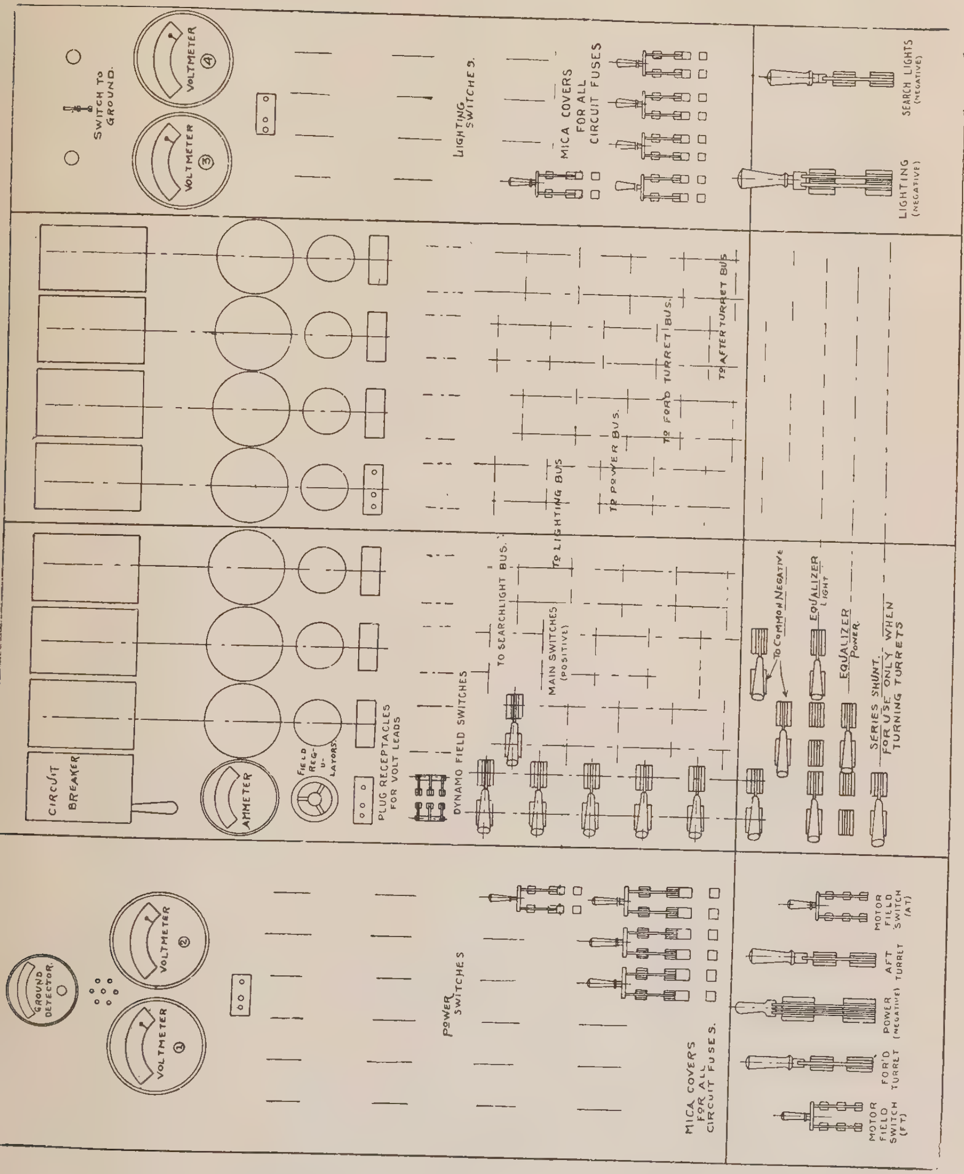

SWITCH TO GROUND
VOLTMETER ④
VOLTMETER ③
LIGHTING SWITCHES
MICA COVERS FOR ALL CIRCUIT FUSES
SEARCH LIGHTS (NEGATIVE)
LIGHTING (NEGATIVE)
TO SEARCHLIGHT BUS
TO LIGHTING BUS
TO POWER BUS
TO FOR'D TURRET BUS
TO AFTER TURRET BUS
MAIN SWITCHES (POSITIVE)
CIRCUIT BREAKER
AMMETER
FIELD REGULATORS
PLUG RECEPTACLES FOR VOLT LEADS
DYNAMO FIELD SWITCHES
TO COMMON NEGATIVE
EQUALIZER LIGHT
EQUALIZER POWER
SERIES SHUNT. FOR USE ONLY WHEN TURNING TURRETS
GROUND DETECTOR
VOLTMETER ②
VOLTMETER ①
POWER SWITCHES
MICA COVERS FOR ALL CIRCUIT FUSES
MOTOR FIELD SWITCH (AT)
AFT TURRET
POWER (NEGATIVE)
FOR'D TURRET
MOTOR FIELD SWITCH (FT)

FIG. 169.—Old Standard Switchboard. Front View

which the generator may be connected to (proceeding in order starting with the upper switch): 1st, search-light bus; 2d, lighting bus; 3d, power bus; 4th, forward turret bus; 5th, after turret bus. In the same vertical row but on lower panel there are four single-pole single-throw switches; the upper one connects the negative leg of the generator to the common negative bus bar, the two middle switches connect the equalizer bars, and the lower switch is to shunt the series field for turret turning, as previously mentioned.

At the left of the generator panel is the power distribution panel, containing as many double-pole single-throw fused switches as may be required. Arranged at the top of this panel is a ground detector with receptacle, then two voltmeters, with plug receptacle underneath. In the center of the power panel at the bottom is a main negative power switch, while on each side are two single-pole switches controlling the negative legs of the turret-turning circuits, the left-hand switch for forward turret and the right-hand switch for after turret. Outside of these last-mentioned switches are the field switches of the turret-turning motors and generator used for turret turning. These are double-pole single-throw switches with an extra set of long switch clips, across which is connected a field discharge resistance.

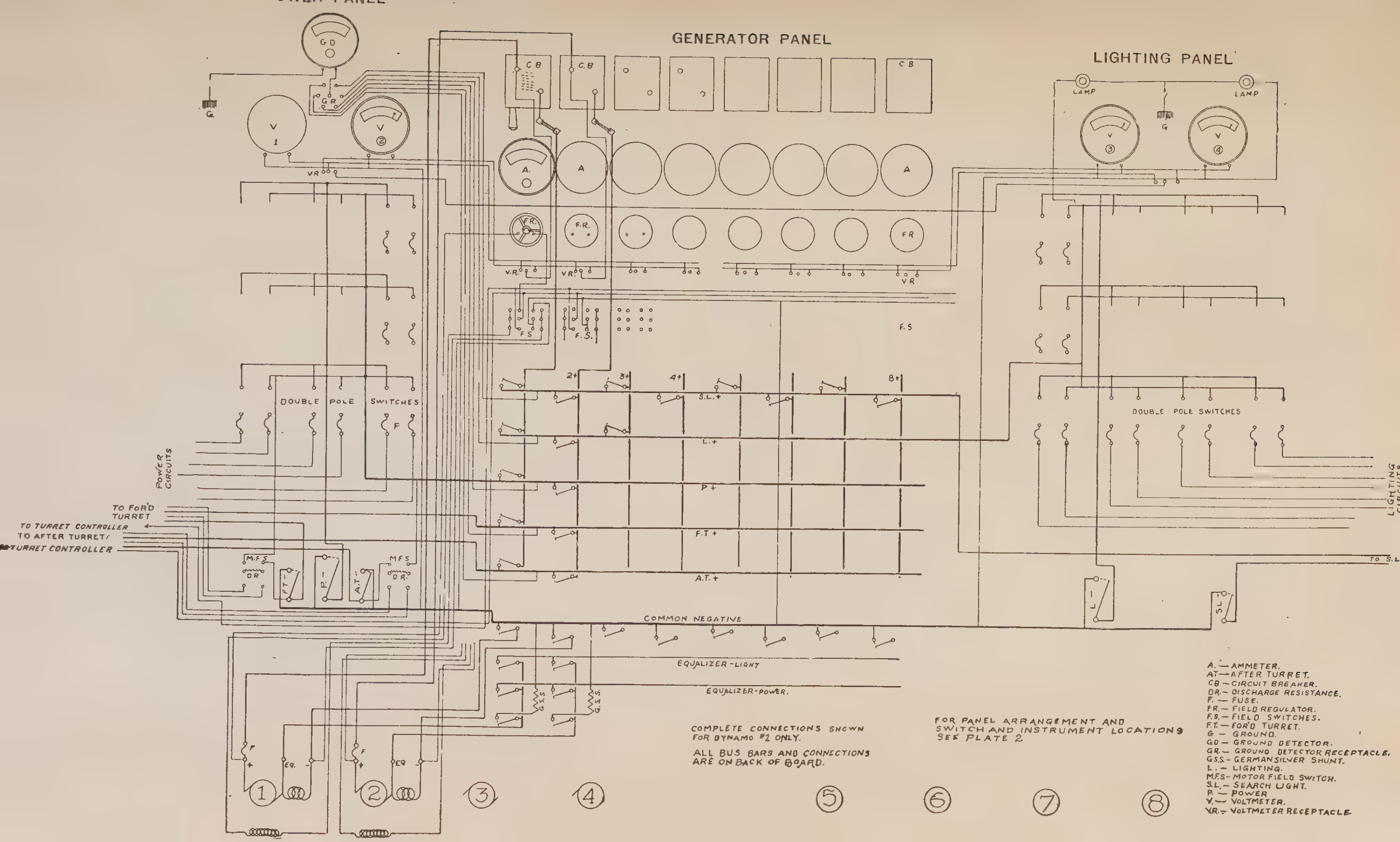
To the right of the generator panel is the lighting distribution panel containing as many double-pole single-throw fused switches as may be required. At the top of this panel is an ordinary lamp ground detector, with a small single-pole switch to break the ground connection (this operation being necessary before using voltmeter ground detector). This panel also contains two voltmeters with plug receptacle underneath. On lower panel are two single-pole main negative switches, one for lighting circuit and the other for search-light circuit.

On each generator headboard there is a main fuse on the positive leg.

All switches on generator panel throw horizontally, being hinged on the *generator* end. For the forward turret, after turret, equalizers and series shunt, removable blade plug switches are used.

Only four blades are supplied for each equalizer, and *not more than two blades* for each of the others, *i. e.,* forward turret, after turret and series shunt. When a switch is open, the clip is to be plugged with a stop which will prevent accidental closing.

The field-control switches allow three methods of field excitation. By throwing the two upper switches the machine is made self-exciting. By throwing the two middle switches the machine is separately excited and controlled from the forward turret. By throwing the two lower switches the machine is separately excited and controlled from the after turret.


GENERATOR PANEL
LIGHTING PANEL
G D
G R
G
V 1
V ②
VR
C B
C.B
A.
A
F.R.
FR
V.R.
F.S.
F.S
LAMP
V ③
V ④
2+
3+
4+
8+
S.L.+
L.+
P+
F.T+
A.T.+
DOUBLE POLE SWITCHES
F
POWER CIRCUITS
LIGHTING CIRCUITS
TO FOR'D TURRET
TO TURRET CONTROLLER
TO AFTER TURRET/
TURRET CONTROLLER
M.F.S
D.R.
F.T.
P.
A.T.
L
S.L.
TO S.L.
COMMON NEGATIVE
EQUALIZER-LIGHT
EQUALIZER-POWER.
G.S.S.
EQ.
EQ
①
②
③
④
⑤
⑥
⑦
⑧

COMPLETE CONNECTIONS SHOWN FOR DYNAMO #1 ONLY.

ALL BUS BARS AND CONNECTIONS ARE ON BACK OF BOARD.

FOR PANEL ARRANGEMENT AND SWITCH AND INSTRUMENT LOCATIONS SEE PLATE 2

A. — AMMETER.
AT — AFTER TURRET.
CB — CIRCUIT BREAKER.
DR. — DISCHARGE RESISTANCE.
F. — FUSE.
FR. — FIELD REGULATOR.
F.S. — FIELD SWITCHES.
F.T. — FOR'D TURRET.
G — GROUND.
GD — GROUND DETECTOR.
GR. — GROUND DETECTOR RECEPTACLE.
G.S.S. — GERMAN SILVER SHUNT.
L. — LIGHTING.
M.F.S. — MOTOR FIELD SWITCH.
S.L. — SEARCH LIGHT.
P. — POWER
V. — VOLTMETER.
V.R. — VOLTMETER RECEPTACLE

Voltmeter Connections.—The voltmeter connections, as shown in Fig. 171, are identical with, but more clearly shown than those in Fig. 170. The plug receptacle on the power panel and the four receptacles for machines Nos. 1, 2, 3 and 4, have a spacing of 1 and 2 inches, whereas the receptacle on the lighting panel and those for machines Nos. 5, 6, 7 and 8, have a spacing of 1½ and 2½ inches. By using the 1-inch plug on any receptacle on the generator panel the voltage of the machine is read on voltmeter No. 1, likewise by using 2-inch plug the voltage can be read on voltmeter No. 2. Similarly, the 1½-inch plug throws voltmeter No. 3 across the generator terminals and the 2½-inch plug throws voltmeter No. 4 across the terminals. Thus we can read the voltage of any two machines on the left-hand and of any two machines on the right panel (four machines in all) simultaneously.

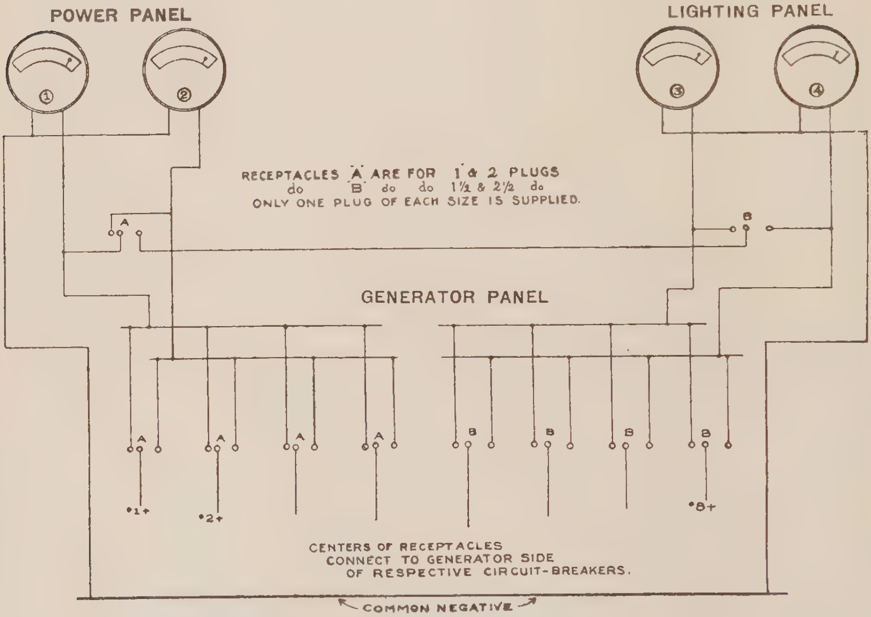

POWER PANEL
LIGHTING PANEL
①
②
③
④
RECEPTACLES A ARE FOR 1 & 2 PLUGS
do B do do 1½ & 2½ do
ONLY ONE PLUG OF EACH SIZE IS SUPPLIED.
A
B
GENERATOR PANEL
A
A
A
A
B
B
B
B
•1+
•2+
•8+
CENTERS OF RECEPTACLES
CONNECT TO GENERATOR SIDE
OF RESPECTIVE CIRCUIT-BREAKERS.
COMMON NEGATIVE

FIG. 171.—Voltmeter Connections on Old Standard Switchboard.

With the 2-inch plug in a receptacle on the generator panel and the 1-inch plug in the receptacle on the power panel, we have voltmeter No. 1 in parallel with voltmeter No. 2 for calibration.

With the 1-inch plug in a receptacle on the generator panel, the 2-inch plug in the receptacle on power panel, and the 1½-inch plug in the receptacle on lighting panel, voltmeters Nos. 1 and 3 are in parallel. By substituting the 2½-inch plug for the 1½-inch plug in the above instrument Nos. 1 and 4 are in parallel. *As only one plug of each spacing* is furnished, it is impossible to make a short circuit or parallel two machines on the voltmeter connections. An inspection of Fig. 171 shows this to be true.

Switchboards of Wyoming and New York Types.

In these ships a return has been made to two dynamo rooms, one situated forward and one aft, in each of which are two generator units. This arrangement necessitates two generator panels and two distribution boards, with arrangements for energizing both boards from either generator panel.

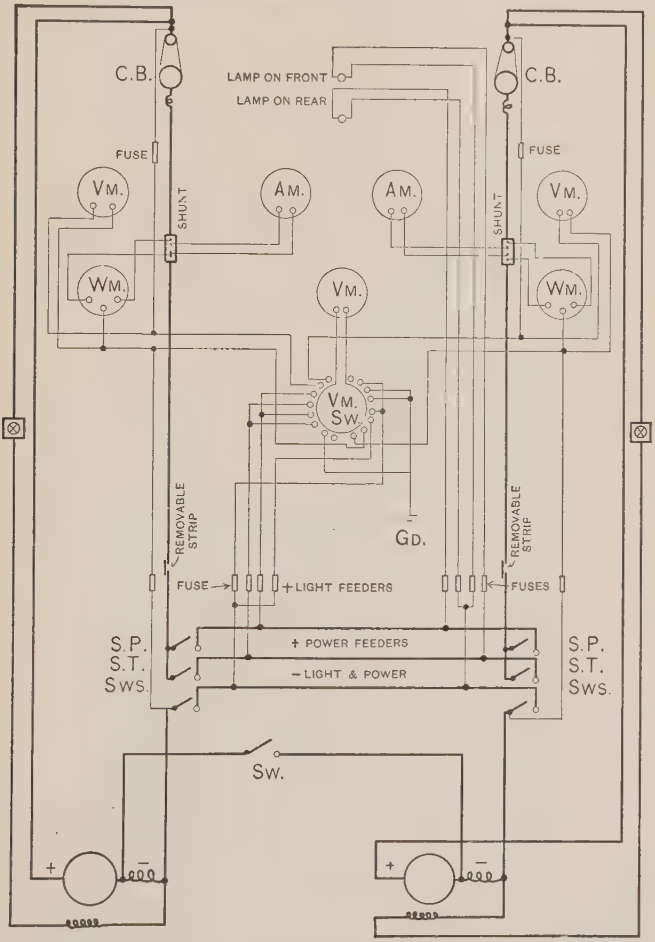

C.B.
LAMP ON FRONT
LAMP ON REAR
C.B.
FUSE
FUSE
VM.
SHUNT
AM.
AM.
SHUNT
VM.
WM.
VM.
WM.
VM. SW.
REMOVABLE STRIP
GD.
REMOVABLE STRIP
FUSE
+ LIGHT FEEDERS
FUSES
S.P. S.T. SWS.
+ POWER FEEDERS
− LIGHT & POWER
S.P. S.T. SWS.
SW.
+
−
+
−

FIG. 172.—Wiring Diagram, Generator Panel. *Wyoming* and *New York*.

The wiring diagram of the generator panel is shown in Fig. 172. The arrangement of busses is similar to that shown in previous types, and the connection of instruments can be followed. The upper row of instruments shows two voltmeters, one to give the terminal voltage of each machine, and two ammeters, for indicating the total load on each generator. Each generator is also provided with a watt-hour meter to record the total power delivered by each machine. This instrument is a Sangamo watt-hour meter and is of the motor type and operates from the same shunt that supplies the ammeter. The voltmeter, shown in the middle, is provided with a selective switch, by means of which the voltage of either generator may be determined, the difference of potential between the + lighting bus and the common − bus, and between the + power bus and the common − bus. The same switch also serves to connect the voltmeter between the + lighting bus and ground, the + power bus and ground and the common − and ground, for purposes of detecting grounds or leaks and indicating the value thereof.

The removable strips, shown in the + bus bars, may be removed to allow the insertion of a standard shunt and ammeter for the purpose of calibrating other ammeters.

Distribution Boards.—These are practically the same as the *Oklahoma* type.

Oklahoma Switchboard.

The *Oklahoma* switchboard is typical of all modern battleship switchboards, except for ships having 3-wire generator systems.

The electric plant consists of four 300 kw., 125-volt turbo-generators, in two dynamo rooms, and is controlled from two generator panels located in the forward and after distribution rooms, in conjunction with the distribution boards, the distribution rooms being adjacent to the respective dynamo rooms.

Fig. 173 shows the forward generator and distribution board, and its wiring diagram is reproduced in Fig. 174. The after board is similar to the forward board, the chief difference lying in the fact that it is not fitted for operating the anchor windlass.

The wiring diagram, Fig. 174, shows the plan of the board as seen *from the rear.* The panels are numbered from left to right *in front* of the board, hence they are shown in reverse order in this plan.

Looking *at the front* of the switchboard, and counting from left to right, there are seven panels; namely, Power Panel No. 1, Power Panel No. 2, Total Power Panel, Generator Panel, Total Lighting Panel, Search-light and Lighting Panel No. 1, Search-light and Lighting Panel No. 2. Each of these will be briefly described. The front view of the panel shows switches, instruments, etc., in their correct locations. In the wiring diagram, in order to make the wiring leads clear, it has been necessary to show some of the

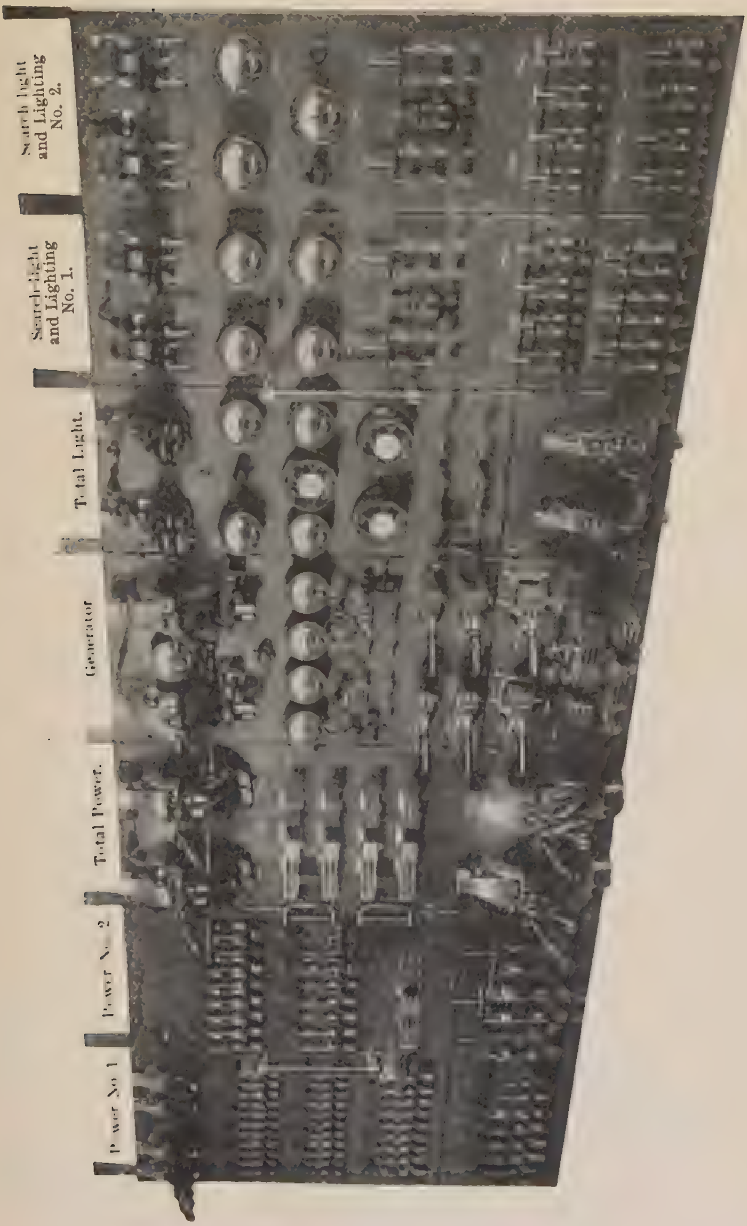

Search-light and Lighting No. 2.
Search-light and Lighting No. 1.
Total Light.
Generator
Total Power.
Power No. 2
Power No. 1

FIG. 173.—Forward Generator and Distribution Board. U. S. S. *Oklahoma.*

instruments, etc., out of their proper locations. Reference should be made both to the front view of the panel and to the wiring diagram.

Generator Panel.—At the top of the board are two single-pole, 2500-ampere, time-limit circuit breakers, in the positive leg of each generator. Each circuit breaker is also fitted with a shunt tripping coil in circuit with a switch which is operated by the emergency tripping device located on the generator itself. The circuit breaker opens when the emergency device operates; and an auxiliary switch is mounted on the dynamo frame, for tripping the circuit breaker from the dynamo room at any time, at the will of the operator.

Between the two circuit breakers is the calibrating voltmeter, also connected as ground detector, with its selective switch directly underneath it.

Below these are the voltmeter and ammeter for each generator, and directly below these is the field control wheel for each generator, the rheostats being located on the back of the board.

Below the field control wheels is a horizontal double-pole, double-throw switch for each generator, which, when thrown toward the center of the panel, disconnects the field rheostat and connects the shunt field of that generator so that it can be controlled from the anchor windlass panel; the anchor windlass being fitted to operate by the Ward-Leonard system, using either of the two forward generators. On the wiring diagram the field rheostat and the control switch are shown underneath the common negative bus.

Beneath the field switch, on each side, is the single-pole switch which connects the positive leg of the generator to the + lighting bus, and underneath that the similar one for the + power bus.

Beneath the above are the single-pole switches for the common negative bus, one for each generator, and beneath these the anchor windlass supply switches, which also operate as equalizer connection. Each of the common negative switches is mechanically interlocked with its own anchor windlass supply switch.

When a generator is being used for anchor windlass, its negative switch is opened, and the series field is thus inoperative. Both switches thrown to the left connect the left-hand generator to the anchor windlass, and open its negative switch; when thrown to the right, the right-hand generator becomes similarly connected; and the other generator, in either case, feeds the busses on the generator panel. When the anchor windlass switches are thrown, each on its own side, the two generators are equalized by these switches. An inspection of the wiring diagram makes this clear.

Total Power Panel.—At the top are two 5000-ampere single-pole circuit breakers, which control all the miscellaneous power circuits on the board.

Between these is the lamp ground detector for power circuits, and directly underneath it the ground switch.

Beneath these are two horizontal double-pole, double-throw switches, the upper one for miscellaneous power, the lower one for turret and search-light power. When thrown one way they derive power from their own generator panel; the other way, from the distant generator panel.

Beneath these are two 5000-ampere, single-pole circuit breakers which, when closed, supply power to the after distribution board. These are of the interlocking type, previously described.

Power Panel No. 1.—At the top are four single-pole circuit breakers which control the forward turrets.

Below these are four rows of vertical double-pole switches, each leg of each switch fused; these switches energize various miscellaneous power circuits.

Power Panel No. 2.—At the top are two rows of vertical double-pole, fused switches for miscellaneous power circuits.

Beneath these is a horizontal single-pole, double-throw switch which is on the positive leg of the anchor windlass circuit, and throws in either of the machines.

Beneath this is another row of vertical double-pole fused switches for miscellaneous power circuits.

Total Lighting Panel.—At the top are two 800-ampere, single-pole circuit breakers which control all the lighting circuits on the forward board. Between these is the lamp ground detector for lighting circuits, with its ground switch directly beneath.

Beneath these are three rows of instruments. In the first row are a voltmeter; then its selective switch for (1) forward lighting, (2) forward power, (3) lighting bus feeders from after board, (4) power bus feeders from after board; then an ammeter for turret and search-light power.

In the next row are an ammeter for total lighting, a watt-hour meter for total lighting, and an ammeter for miscellaneous power.

In the next row are two watt-hour meters, one for each generator. (In wiring diagram shown on generator panel.)

Below these is a horizontal double-pole, double-throw switch which, when thrown one way, energizes the lighting busses from their own generator panel; the other way, from inter-connecting lighting bus feeders.

At the bottom are two 800-ampere single-pole circuit breakers, interlocking type, for energizing inter-connecting bus feeders from the adjacent generator panel.

Search-light and Lighting Panel No. 1.—At the top are two double-pole 200-ampere circuit breakers for two of the forward search-lights, energized from the turret and search-light busses.

Beneath each of these is an ammeter for that search-light.

Below these are two voltmeters; one for total voltage across the lighting, power and search-light busses, with its selective switch to the right; the other for voltage across the four search-light arcs, its selective switch being on the next panel.

Below these are two vertical double-pole, double-throw switches, for the two search-lights. The up-throw is for the main locations of the search-lights on the foremast; the down-throw is for the secondary positions of the lights. Between the circuit breaker and the double-throw switch, one leg of the circuit passes through the search-light rheostat located in an adjoining room. The distant control handle for the rheostat is not on the board, but is adjacent to it.

Between the search-light switches is a double-pole, single-throw fused switch, supplying one of the lighting circuits, and energized from the lighting busses.

Beneath the above are two rows of double-pole, single-throw fused switches, likewise supplying various lighting circuits.

Search-light and Lighting Panel No. 2.—At the top are two double-pole circuit breakers for the other two search-lights, with an ammeter for each light beneath them.

Beneath these are the selective switch for the voltage across the arcs, the voltmeter ground detector, and its selective switch.

Beneath these the arrangement is exactly similar to that on Lighting Panel No. 1.

Switchboards for Vessels Equipped with 240-Volt Generators.

Recently designed battleships are equipped with 300 kw., 240-volt generators, of a type called 3-wire generators (Dobrowolsky system). These generators supply energy to three bus bars on the generator panel. The middle bus corresponds to the neutral in the 3-wire system of distribution, and 120 volts is maintained between this neutral bus and the two outer busses, the potential between the two outer busses being full voltage of generator, 240 volts.

Energy to power circuits is supplied at 240 volts, and to lighting circuits at 120 volts. Search-lights in this system are on lighting, not power, busses.

The ship's lighting and search-lights are supplied by a 2-wire system, each feeder switch being connected to the neutral and one outer bus. The feeder connections are arranged so as to have the load as nearly balanced as possible. The voltage of the neutral bus, with unbalanced load, is maintained by means of a compensator or balance coil. The compensator is a reactance coil or auto-transformer, in which the two ends are connected to electrically opposite coils in the armature by means of slip rings, and the middle part to the neutral bus. The theory of this is discussed elsewhere.

The *general plan of distribution* is similar to the *Oklahoma* type. The switchboards are divided into panels for generator control, total power, total lighting, power distribution, lighting distribution and search-light distribution.

For vessels having electric propulsion there is an additional panel for main-drive generator field excitation, and electrically driven engine-room auxiliaries. These vessels have the 300 kw. generator panels and the engine-room auxiliary panels in the machinery space, and the other panels in the distribution rooms. Vessels equipped for steam propulsion have all of the panels assembled in one switchboard for each distribution room.

Fig. 175 shows the front view of the generator and main-drive auxiliary panels, for a battleship equipped with 3-wire generators and electric drive.

Fig. 176 shows the wiring diagram, *front view,* of the same panel.

Fig. 177 shows the wiring diagram, *rear view,* of the distribution switchboard of the same vessel.

In the following description, reference should be made frequently to the accompanying figures, as the figures are largely self-explanatory, after the *Oklahoma* switchboard has been studied.

Generator Panel.—Referring to Fig. 176, each generator has leading from the brushes a series interpole and a series field, on each leg of the circuit. Between the interpole and the series field, on each leg, is an equalizer connection. The shunt fields of the generators are not shown on the diagram. Thus it is seen that each generator has a positive, a negative, a neutral, and positive and negative equalizer connections, five in all. Each of these is connected to a corresponding bus on its generator panel. Circuit breakers marked A are for the positive and negative leads, and are fitted to open on reverse current as well as overload, and circuit breakers B are for the equalizer leads, and open on overload only. There is an ammeter in each side of the line, a voltmeter, a field control handle (not shown in wiring diagram), a watt-hour meter, and a triple-pole switch for connecting the generator to the positive, negative and neutral busses. The location of the instruments, etc., is shown in Fig. 175.

Main-Drive Auxiliary Panels.—These are fitted with double-throw switches so as to derive power either from adjacent or from remote generator board.. The only part requiring explanation is the booster motor generator. The motor is driven by direct current from the 240-volt busses. The generator field is supplied with direct current through a rheostat, so that its excitation can be varied. By tracing out the leads, it is seen that the armature of the generator is in series with the 240-volt main-drive busses, and that this circuit leads to the alternating-current generator fields, passing through the main control room, as shown at the top of Auxiliary Panel No. 1. The voltage across the alternating-current generator field is thus 240 volts, plus or minus whatever voltage is generated in the booster.

Total Power Panel.—This panel has two single-pole circuit breakers for miscellaneous power, and two double-pole, double-throw switches, one for miscellaneous power and one for turret power, which may be derived either from the adjacent generator panel or through inter-connecting bus feeders from remote switchboard. The inter-connecting bus feeders are connected by interlocking circuit breakers to the power busses on the adjacent panel, for supplying power to the remote distribution board. Turret and miscellaneous power ammeters, and voltmeter, are installed on this panel if space is available, but if not (and it usually is not) they are installed on the distribution panels. It will be noted that this panel is practically identical with the total power panel of the *Oklahoma.*

Total Lighting Panel.—At the top of the panel is the circuit breaker for total lighting. This is a special type of circuit breaker, suitable for 3-wire systems, and consists practically of two single-pole breakers, one in each outer wire, with an additional tripping coil in the neutral wire. There is no breaker in the neutral wire, for the reason that, if the neutral should open when there was considerable unbalanced current, the potential difference of lamps on one side of neutral would drop and on the other side would rise. This rise in potential might be enough to injure some of the circuits.

The breaker therefore opens the two outer wires, (1) for an overload in either, and (2) for an overload in neutral.

Below the circuit breaker are three voltmeters, for giving the voltage across various busses.

Below these is a triple-pole switch so that lighting panels may draw power from either generator room. Beneath this is a triple-pole circuit breaker of interlocking type, for energizing the three inter-connecting bus feeders to the distant lighting panel. Ammeters are provided on the lighting distribution panel to show the load on each side of the neutral lighting bus.

Power and Lighting Distribution Panels.—These panels are equipped with fused switches and circuit breakers as required for the control of the various circuits. In general, feeders carrying over 500 amperes are controlled by plain overload circuit breakers instead of switches. Ground detector voltmeter and watt-hour meters for light and power are installed in the most convenient locations.

Search-light Panels.—There is a double-pole circuit breaker and ammeter for each search-light, and a voltmeter to give potential across any search-light arc supplied from the panel.

Illumination.—The switchboards are illuminated by fixtures which are not attached to the boards, but are dropped down from the deck and supplied with current direct from the main busses.

OPERATION.

The operation of generators, with the various types of switchboards, differs somewhat, depending on the type of generator as well as switchboard. The general principles, with method of procedure, for two compound generators, are given in Volume I and also in Chapter XXIII, Vol. II.

CHAPTER XI.

WIRES.

The size of a conductor necessary to carry a given current is determined by its area of cross-section, and this may be any of the ordinary shapes; square, rectangular or circular, the latter being the most common. If the cross-sectional area be circular, as a wire, the conducting area may be one large wire, or a collection of wires stranded together carrying the current in parallel and whose area is collectively equal to the large wire.

Circular Mil.—Electricians use as a unit of sectional measure an area whose value is one **circular mil.** The mil is a linear measure and is equal to .001 of an inch. If a round wire has a diameter of one mil, then the area of cross-section of that wire is one circular mil.

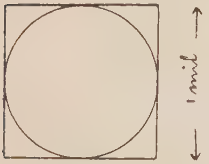


FIG. 178.

The **square mil** is sometimes used as a unit of area, being the area of a square .001 inch on a side. The number of circular mils multiplied by .7854 gives the number of square mils; and the number of square mils multiplied by 1.273 gives the number of circular mils. This is shown in the relation between the area of a circle and the circumscribed square, 1 mil on the side (Fig. 178),

$$\text{area of circle} = \frac{\pi d^2}{4} = \frac{3.1416}{4} \times 1^2 = .7854 \text{ sq. mil} = 1 \text{ cir. mil},$$

$$\text{area of square} = 1 \times 1 = 1 \text{ sq. mil},$$

or

$$.7854 \times 1 \text{ sq. mil} = 1 \text{ cir. mil},$$

$$1 \text{ cir. mil} \times 1.273 = 1 \text{ sq. mil}.$$

When the diameter of the wire is .001 inch or one mil, the circular area is $.001^2 \times .7854 = .0000007854$ square inch, or one circular mil $= .0000007854$ square inch.

Suppose it was required to express in circular mils the area of cross-section of a wire 1 inch in diameter. The area of this circle would be

$$\frac{\pi d^2}{4} = .7854 \times 1^2 = .7854 \text{ sq. in.}$$

But

$$1 \text{ cir. mil} = .0000007854 \text{ sq. in.}$$

$$\therefore \qquad \text{No. of cir. mils} = \frac{.7854}{.0000007854} = 1{,}000{,}000.$$

This number is the square of the diameter expressed in mils, as one inch equals one thousand mils; hence we have the rule: To express the cross-sectional area of wires in circular mils, we multiply the diameter of the wire expressed in mils by itself; or, in other words, *the square of the diameter expressed in mils is equal to the area in circular mils.*

To express the cross-sectional area of a rectangular or square-shaped conductor in circular mils, it is necessary first to find the area in square inches, and reduce that to circular mils.

1 sq. inch = 1000 × 1000 = 1,000,000 sq. mils,
1 sq. mil = 1.273 cir. mils,
or 1 sq. inch = 1,273,000 cir. mils.

So to find the area of a bus bar, for instance, first find its area in square inches and multiply by 1,273,000, and the result will be circular mils.

The size of the wire in circular mils is used in specifying sizes in the naval service.

Wire Sizes.—All single strands forming the conductors are of the diameters given in Table I.

TABLE I.

Diameter over copper, in inches.	Cross-section.		Ohms per 1000 feet.		Pounds per 1000 feet.
	Circular mils.	Square inches	25° C. (=77° F.).	65° C. (=149° F.).	
0.090	8,230	0.00647	1.28	1.48	24.90
0.080	6,530	0.00513	1.62	1.87	19.80
0.072	5,180	0.00407	2.04	2.36	15.70
0.064	4,110	0.00323	2.58	2.97	12.40
0.057	3,260	0.00256	3.25	3.75	9.86
0.050	2,580	0.00203	4.09	4.73	7.82
0.045	2,050	0.00161	5.16	5.96	6.20
0.040	1,620	0.00128	6.51	7.52	4.92
0.036	1,290	0.00101	8.21	9.48	3.90
0.032	1,020	0.00080	10.40	12.00	3.09
0.028	810	0.00063	13.10	15.10	2.45
0.025	642	0.00050	16.50	19.00	1.94
0.023	509	0.00040	20.80	24.00	1.54
0.020	404	0.00032	26.20	30.20	1.22
0.018	320	0.00025	33.00	38.10	0.97
0.016	254	0.00020	41.60	48.10	0.769
0.014	202	0.00016	52.50	60.60	0.610
0.012	160	0.00013	66.20	76.40	0.484
0.011	127	0.00010	83.50	96.40	0.384
0.010	101	0.00008	105.00	122.00	0.304
0.007	50	0.00004	211.00	244.00	0.152

Conductivity.—(a) The *standard of resistivity* is that given in Table I.

(b) In all *stranded conductors* the sum of the circular mils of the individual strands shall not be less than 98½ per cent of the sum of the areas of the stated number of conductors, each of the standard diameter.

(c) In *tinned conductors,* where the diameter is increased, in calculating the conductivity (or resistivity) allowance is made for the decrease in conductivity caused by the envelope of tin, which, while adding to the diameter, gives but fractional values of conductivity.

(d) These values are not less than the following:

TABLE II.

Diameter.	Per cent.	Diameter.	Per cent.
0.091	97.5	0.025	95.4
0.072	97	0.023	95.2
0.064	97	0.020	95
0.057	96.8	0.018	94.8
0.050	96.6	0.016	94.6
0.045	96.4	0.014	94.4
0.040	96.2	0.012	94.2
0.036	96	0.011	94
0.032	95.8	0.010	93.8
0.028	95.6		

Construction of Conductors.

Material.—All conductors are of soft-annealed pure copper wire, and each wire is thoroughly and evenly tinned.

Stranded Conductors.—Single wires are used only for small conductors. When greater conducting area than .057-inch diameter is used, the conductor is stranded in a series of 7, 19, 37, 61, 91, 127 wires. The conductor consists of one central strand, with the remainder laid around it concentrically, each layer twisted in the opposite direction from each preceding layer.

Construction.—The construction of the conductors and the diameters over each of the elements are given in Table III.

For *twin conductor* the "number of wires in strand," "diameter of wire" and "diameter over copper" is the same as in Table III.

Calculation for Size.

In calculating the size of wires for a certain circuit on board ship, two requirements must be met: first, the wires must be large enough to carry their loads without undue heating, and second, they must be large enough so that the fall of potential or *drop* due to the resistance of the conductors themselves shall not exceed a certain amount.

LIGHTING AND POWER WIRE—SINGLE CONDUCTORS.

Approximate circular mils.	Plain.								Armored.			Leaded and armored.			Approximate circular mils.
												Lead.			
	Actual circular mils.	Wires in strand.	Diameter of wire.	Diameter over copper.	Thickness, rubber.	Diameter over rubber.	Diameter over tape.	Diameter over braid.	Diameter over steel.	Ends.	Size, steel wire.	Thickness (one side).	Diameter over.	Diameter over steel.	
4,000	4,494	7	0.025	0.076	0.060	0.196	0.228	0.268	0.338	5	0.0126	0.031	0.290	0.450	4,000
9,000	9,030	7	0.036	0.108	0.065	0.237	0.269	0.309	0.379	5	0.0126	0.035	0.339	0.499	9,000
11,000	11,340	7	0.040	0.121	0.065	0.251	0.283	0.323	0.393	5	0.0126	0.035	0.353	0.523	11,000
14,000	14,350	7	0.045	0.136	0.065	0.266	0.298	0.338	0.408	5	0.0126	0.035	0.368	0.538	14,000
18,000	18,060	7	0.050	0.152	0.070	0.292	0.324	0.384	0.454	5	0.0126	0.040	0.404	0.574	18,000
23,000	22,820	7	0.057	0.171	0.070	0.311	0.343	0.403	0.473	5	0.0126	0.040	0.423	0.593	23,000
30,000	30,780	19	0.040	0.201	0.075	0.351	0.383	0.443	0.513	5	0.0126	0.040	0.453	0.623	30,000
40,000	38,950	19	0.045	0.226	0.075	0.376	0.408	0.468	0.538	5	0.0126	0.045	0.498	0.668	40,000
50,000	49,020	19	0.050	0.254	0.080	0.414	0.446	0.506	0.576	5	0.0126	0.045	0.536	0.706	50,000
60,000	59,940	37	0.040	0.282	0.080	0.442	0.506	0.570	0.640	6	0.0126	0.045	0.596	0.766	60,000
75,000	75,850	37	0.045	0.317	0.085	0.487	0.551	0.615	0.685	6	0.0126	0.050	0.651	0.821	75,000
100,000	98,820	61	0.040	0.363	0.085	0.533	0.597	0.661	0.731	7	0.0126	0.050	0.697	0.867	100,000
125,000	125,050	61	0.045	0.407	0.095	0.597	0.661	0.725	0.795	7	0.0126	0.050	0.761	0.931	125,000
150,000	157,380	61	0.050	0.457	0.095	0.647	0.711	0.773	0.845	8	0.0126	0.060	0.833	1.003	150,000
200,000	198,860	61	0.057	0.514	0.100	0.713	0.777	0.841	0.911	8	0.0126	0.060	0.897	1.067	200,000
250,000	250,710	61	0.064	0.577	0.110	0.796	0.860	0.924	0.994	9	0.0126	0.070	1.000	1.170	250,000
300,000	296,660	91	0.057	0.628	0.120	0.868	0.932	0.996	1.066	10	0.0126	0.070	1.072	1.242	300,000
375,000	374,010	91	0.064	0.705	0.125	0.955	1.019	1.083	1.153	10	0.0126	0.080	1.179	1.349	375,000
400,000	414,020	127	0.057	0.742	0.130	1.002	1.066	1.130	1.200	11	0.0126	0.080	1.226	1.396	400,000
500,000	521,970	127	0.064	0.833	0.135	1.103	1.167	1.231	1.301	12	0.0126	0.080	1.326	1.496	500,000
650,000	657,860	127	0.072	0.935	0.135	1.205	1.269	1.334	1.404	13	0.0126	0.090	1.449	1.619	650,000
800,000	829,310	127	0.080	1.051	0.135	1.320	1.384	1.449	1.519	14	0.0126	0.090	1.564	1.734	800,000

The first requirement is met by the standard specifications which state that the safe-carrying load shall be at the rate of 1000 amperes per square inch of conductor, and experiment shows that this proportion is entirely safe, the factor of safety being sufficient. The second requirement is that the total drop from the generator to the farthest lamp shall be not more than 2½ per cent of the total difference of potential at the generator, this drop being due to the resistance of the conductors.

When the wire list is being prepared it is usual to mark the location and character of all lights on the blue prints of the ship, and draw the mains, by which means the exact total load the mains must carry is determined, and also the length of the mains. The proper feeding center is then determined on and the length of the feeder to the switchboard measured.

The resistance of a foot of copper wire at ordinary room temperature is assumed for practical purposes as 10.8 ohms for a wire 1 mil in diameter and 1 foot long, or 1 mil foot.

Since resistance varies directly as the length and inversely as the cross-sectional area the general formula for resistance would be:

$$R=\frac{l}{a}\rho, \text{ or } R=\frac{l}{a}\times 10.8, \qquad \text{(a)}$$

where

R = resistance in ohms,
l = length in feet,
a = area in circular mils,
ρ = specific resistance = 10.8 for practical purposes.

From Ohms' law $I=\frac{e}{R}$.

If R is the resistance of the conductor, I the current flowing, then e is the drop of potential in the conductor. Substituting in (a) we have

$$a=\frac{10.8\times l\times I}{e}, \qquad \text{(b)}$$

and, thus, knowing the quantities l, I and e, the area in circular mils can be obtained.

The calculations can best be illustrated by an example showing how to find the sizes for feeder, mains and branches in a typical feeder circuit to meet the two requirements for heating and drop. To take a simple case, suppose a main runs along the gun deck of a vessel, lights being taken from it along its length, and that the main is supplied by a feeder from the switchboard at a point such that the total current is equally divided, or nearly so, on each side of the feeding center. This is represented by the figure.

Fig. 179 represents a main of total double length of 200 feet fed by a feeder of 100 feet double-carrying length. There are thirty 40-watt tungsten lamps represented on each side of the feeder. Calculation of wire sizes is made on a basis of .3 ampere per lamp. The total load then due to the 30 lamps on one side is $.3 \times 30 = 9$ amperes. The feeder must supply 18 amperes, and the feeding center at such a point that the load on each side of the feeder is equal, viz., 9 amperes.

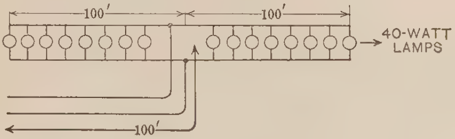


Fig. 179.

As a rule allowance is made for half the drop in the feeder, and half in the mains. (In case the feeder is very much shorter than the mains, this, of course, can be varied, but the total drop must not exceed 2½ per cent.) The allowed drop is

$$e_t = 2\tfrac{1}{2} \times 120 = 3 \text{ volts,}$$

for the feeder

$$e_f = \tfrac{3}{2} = 1.5 \text{ volts.}$$

To ensure sufficient size for heating, the load must not exceed 1 ampere per 1000 C. M. Then considering the heating effect alone:

$$a = 18 \times 1000 = 18{,}000 \text{ C. M.} \quad \text{Then from (b)}$$

$$e_f = \frac{200 \times 18 \times 10.8}{18{,}000} = 2.16 \text{ volts.}$$

This size is large enough for heating, but too small for the allowed drop. Using the allowed drop, we have from (b)

$$a = \frac{10.8 \times 200 \times 18}{1.5} = 25{,}920 \text{ C. M.}$$

The nearest manufactured size to this is 22,820 C. M. Using this value

$$e_f = \frac{10.8 \times 200 \times 18}{22{,}820} = 1.70 \text{ volts.}$$

Now taking up the drop in the mains, it is seen that there are 9 amperes carried 100 feet on each side of the feeding center.

The whole load of 9 amperes is not carried the whole length of 100 double, or 200 feet, and the drop is proportional to the resistance. The lamps are taken off at practically equal distances, so the drop can be calculated on any average resistance, or for an average distance, or half the whole distance. In other words, the calculated drop for the whole distance is twice the actual drop.

It will be shown that the drop in any of the branches is practically nothing, so that the maximum drop allowed in the mains, counting the total length is

$$3=1.70+\frac{x}{2} \text{ or } x=2.60,$$

or

$$a=\frac{200\times 9\times 10.8}{2.60}=7477.$$

Using the nearest manufactured size, 9030 circular mils

$$e_m=\frac{200\times 9\times 10.8}{9030}=2.15.$$

The total drop then is $1.70+\frac{2.15}{2}=2.78$, which is within the 2½ per cent limit.

All branch wire is 4494 circular mils, so the drop in a branch 50 double feet would be

$$e=\frac{50\times .3\times 10.8}{4494}=.0336,$$

or per single foot of mains as installed $\frac{.0336}{25}=.0013.$

The size of wire for this circuit would then be: feeder 22,820 circular mils; mains 9030 circular mils, and branches 4494 circular mils.

The feeder might be made smaller and the mains larger and still be within the limit and the selection would depend upon the quantity of similar-sized wire used in other circuits, so the different sizes will be as few as possible.

If a feeder supplies more than one set of mains, the drop in the subfeeders must be calculated and added to the other calculations for feeders and mains.

When calculating for loops, it is only necessary to allow for a length equal to one-half the length of the loop; that is, if the loop is 200 double feet, each side of the feeder would be 100 double feet or 200 single feet, or allowing for an average length, it would be 100 single feet, or half the total length of the loop. The current for each 100 single feet would be half the total current carried by the feeder.

The calculations above are based on a unit of resistance at 77° F. and if the temperature increases above that limit, the resistance will also increase, causing an increase in the drop, but usually there is sufficient margin not to exceed the 2½ per cent allowed.

This calculation for drop shows why lamps that require a lower voltage to produce their standard candle-power should be placed far from the generator, and those that require higher voltage near the generator where the drop is least.

In calculating the drop in power circuits, it is usual to allow a little greater drop, 5 per cent usually being allowed, for here drop is not of so much importance, and of course all the drop takes place in the feeder from the switchboard to the motor panel, making the calculation very simple.

Insulation of Conductors.

The conductor is covered with:

1. A layer of *vulcanized rubber compound* containing 39 to 42 per cent pure rubber. The remainder of inorganic mineral filler.
2. A layer of *cotton tape* filled with a rubber insulating compound.
3. A *braid* of cotton, linen or silk closely woven.

Small stranded conductors are usually covered with a winding of soft cotton threads to prevent adhesion between the wire and the insulation and thereby facilitate the removal of insulation at the joints.

Multiple conductors, cable, and conductors for special uses, are insulated differently in some respects from the above, as will be noted later.

Types of Conductors.

The finished conductors now used in the naval service are of three types, known from their exterior construction as:

1. **Plain.**—Finished with plain braid as described above.
2. **Armored.**—The "plain" finished conductor is covered with a woven galvanized steel armor for protection. The weave is of the "basket" type. The size of the steel wire is .0126 inch. For some purposes hard-drawn copper wire is used instead of steel.
3. **Leaded and Armored.**—The conductor covered with rubber compound and tape as above, then:
    (1) A lead sheath, thickness from .035 to .11 inch, according to the size of the conductor or cable.
    (2) A layer of acid-free compound.
    (3) A layer of tape.
    (4) A layer of acid-free compound.
    (5) A layer of tape.
    (6) Galvanized steel armor.

Classification of Conductors.

All electrical conductors used on naval vessels are classified as follows:

1. **Lighting and Power Conductors.**—Used on light and power circuits.
    (1) **Single Conductors.**—Made in all three types.

(2) **Twin Conductors.**—Made in all three types. Each conductor is insulated with a layer of tape as described above. The two conductors are then grouped together, filled with rubber compound to approach circularity of section and laid up with a twist. Then there is put on a layer of tape and a close braid. This constitutes the "plain" type. The "leaded and armored" type and the "armored" type are made in the same way as the "plain" type with the addition of layers of material described above under those types.

(3) **Four Conductor Lighting.**—Made in all three types. Construction is the same as *twin conductor* and the four conductors grouped in the same manner as described for two conductors.

(4) **Flexible conductors,** in four forms as follows:

(A) **Portable,** used for portable lights. This conductor consists of two conductors, made up as follows for plain type. For each conductor:

(a) Twenty-five strands of tinned copper wire, .01-inch diameter.
(b) A close wrapping of thread.
(c) A layer of rubber compound.
(d) A braid of cotton thread.
(e) The two conductors grouped, filled with waterproofed jute laterals to approach circularity of section, laid up with a twist.
(f) A layer of rubber compound.
(g) A close braid of cotton thread.

This is also made in armored type, in the same way with the steel armor added.

(B) **Silk.**—For movable lighting fixtures, not waterproof, made in plain type only. It consists of two conductors made as follows:

(a), (b) and (c) same as *portable.*
(d) A close braid of two-ply twilled silk.
(e) The conductors twisted together.

(C) **Diving.**—Must be strong and watertight. Made in plain type. It consists of two conductors made as follows:

(a) Seven strands wire, .032-inch diameter.
(b) A layer of rubber compound.
(c) Two conductors grouped and filled with rubber compound.
(d) Another layer of rubber compound.
(e) Close braid of linen thread.
(f) A second braid of linen thread.

(D) **Telephone Cord.**—In plain type only. Consists of two conductors and is made as follows:

(a), (b), (c) and (d) same as *portable* except wire .007-inch diameter.

- (e) The two conductors twisted together.
- (f) Filled with rubber compound.
- (g) Close braid waterproofed.

2. **Bell Wire.**—

(1) **Bell Wire.**—Used for connections to bells and made up as follows:

(a), (b), (c) and (d) same as *portable* except seven strands of wire .02-inch diameter, and the braid not saturated with rubber compound.

(2) **Bell cord** made as:

- (a) Bell cord, double.
- (b) Bell cord, triple.

Each conductor is made in the same way as "flexible conductor, silk."

3. **Cables.**—

(1) **Interior Communication.**—The unit conductors are constructed in the same manner as *bell wire*. To form the cable, plain type:

(a) The required number of unit conductors are grouped together and filled with rubber compound, and laid up with a twist. Then,

- (b) A layer of tape.
- (c) A layer of rubber compound.
- (d) A layer of tape.
- (e) A close braid.

The cable is made in plain, armored, and armored and leaded types.

(2) **Telephone Cable.**—Unit conductors are made up in the same way as *bell wire*. Each pair of unit conductors is filled with rubber compound and twisted together. One unit conductor of each pair has three adjacent black threads woven in the white braid. To form the completed cable, the requisite number of pairs are grouped together and filled with rubber compound. They are laid up with a twist. The pairs of each layer are twisted in the opposite direction to those of the preceding layer. The whole is then finished in the same manner as interior-communication cable.

Tests.

All conductors after completion are subjected to the following tests:

1. **High Potential Test.**—The conductor is subjected to a test voltage of from 1500 volts for telephone cord to 4500 volts for single conductor of 500,000 cm. and over. This test is made after immersion of the finished conductor in fresh water at a temperature of 22° C. for 24 hours, for watertight conductors. The test to be completed not less than three days after vulcanization. For leaded and armored conductors and non-watertight conductors the test is made with dry conductor suspended in the air.

2. **Insulation Resistance Test.**—This test is made with the conductors still immersed (for watertight conductors). It is made by direct deflec-

tion method at a potential of 500 volts direct current after five minutes electrification.

For leaded conductors the test is between conductor and ground; for twin conductors between conductors and ground. The insulation resistance required is 500 megohms per 1000 feet for bell wire, and 800 to 1000 megohms per knot for other conductors.

Silk and bell cord and telephone cord are not subjected to this test.

Problems on Size and Drop in Wires.

(The resistance of one foot of copper wire, 1 circular mil in diameter is taken at 10.78 ohms.)

1. A motor receives 100 kilowatts of power at a distance of 10 miles from a generator, and takes a current of 20 amperes. The loss in the wires is to be 10 per cent of the generator output. Find (1) the voltage at the motor, (2) at the generator and (3) the diameter in mils of the line wires.

Ans. 1. 5000 volts.
2. 5555.5 volts.
3. 202.5 mils.

2. A feeder from a generator whose voltage is 110 volts is 100 feet to its feeding center. On one side of the feeding center it supplies a motor that takes 30 amperes and is 300 feet away. On the other side, it supplies 40 incandescent lamps each taking .5 ampere and grouped 200 feet away, and beyond these two arc lamps in series, each taking 5 amperes. Allowing 2 per cent drop in the feeder, calculate the size necessary. If the size of the wire supplying the lights is 33.332 circular mils, find the voltage across each arc lamp. Calculate the size required for the motor mains, allowing 5 per cent drop.

Ans. 1. 53.900 cir. mils.
2. 52.28 volts.
3. 36.000 cir. mils.

3. What size wire is required to deliver current at 110 volts to a motor of 10-horsepower output and 80 per cent efficiency? The E. M. F. of the generator is 125 volts and the motor is 500 feet away.

Ans. 60.943 cir. mils

CHAPTER XII.

WIRING.

The wiring of ships in the navy presents peculiarities, though as a rule it all follows one general system. The distribution of the current in ships in the service for lighting and power purposes varies with the size and class of ship, and to a certain extent with the time of the installation. The principal modifications in the wiring from time to time are intended to effect saving of current and at the same time equalize the general "drop" or fall of potential around the different circuits.

In the early days of application of electricity to vessels, the distribution of current was a comparatively simple matter, as electric lighting was the only consideration, but the demand for current for power has increased at such a rate that the general question of supply and distribution is one that depends almost wholly on power, the lighting current forming only a small percentage of the whole.

Circuits.

There are three classes of circuits, each being entirely separate and distinct from the others. They are named:

(1) **Search-light circuits.**
(2) **Lighting circuits.**
(3) **Power circuits.**

Search-light Circuits.—Each search-light has a separate feeder leading from the search-light panel, through a double-pole fused switch, rheostat, ammeter and double-pole automatic circuit breaker direct to the terminal in the search-light pedestal. One voltmeter is mounted on the search-light panel.

Lighting Circuits.—The lighting system is divided into two divisions, each division having separate feeders and separate mains:

(1) **Battle service.**
(2) **Lighting service.**

The **battle service** includes every light installed below the protective deck and every light above the protective deck whose use is necessary when the ship is in action. This includes lights for operation of guns, at ammunition hoists, at boat cranes, at controllers, in military tops, on search-light platforms, in conning-tower, in turrets, lights in chart houses and pilot house, all signal and running lights, binnacle lights, instrument lamps, at blowers above protective deck and in passageways and compartments used in time of action.

The **lighting service** includes all lights not on the battle service, lights intended for general illumination in living spaces, passageways, offices, store rooms and cabins. This is still further subdivided into "general lighting circuit" and "night lighting circuit."

The **auxiliary lighting circuit** is fed through the interior communication switchboard from storage batteries. The circuit is closed through a single relay magnet. The coil keeps the circuit open as long as there is voltage on the generator board. When voltage fails, the coil operates and closes the auxiliary circuit through the storage battery. If voltage comes on, the coil opens the auxiliary circuit. The dynamo rooms, distribution rooms, central, plotting room and interior communication room can be lighted from this circuit.

Power Circuits.—Large motors are fed by separate feeders direct from the distribution board; the small motors from the auxiliary panels about the ship.

General Plan of Wiring for Lighting Circuits.

The wiring plan in general use is that known as the **two-wire feeder** system. Each circuit is complete in itself through each lamp and through the source of supply. This system is in contrast to that using one wire with a common return through the body or framework of the ship.

The **feeders** are the conductors that lead from the switchboard or distribution boards direct to their feeding centers, and they supply or feed currents to the mains. If of short lengths, the feeders are unbroken from the switchboard to their feeder centers, but if of long lengths they are broken in feeder junction boxes, for the purpose of testing or ease in installing. No lights are taken from the feeders.

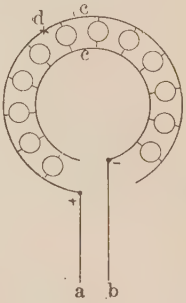
A **bus feeder** is a feeder that runs from a switchboard to a distribution board, or from one distribution board to another, feeding current to the bus bars on the latter.

The **mains** are the conductors that run in the vicinity of the places to be lighted, and are fed by the feeders. The mains are broken at places where lights are to be taken off, by means of distribution or junction boxes, and from these boxes, conductors are run to the lamps. These small conductors from the mains to the lamps are called **branches.**

Long lengths of mains are undesirable and should be avoided where possible, but it frequently happens these have to be installed along the upper decks and in passageways. These long lengths suffer considerable drop of potential due to their resistance, and the lamps at places far from the feeding centers consequently burn dimmer than those nearer the source of supply.

(This assumes that the lamp gives its rated candle-power at the standard voltage.) This is partially remedied by using at the far ends of the mains, lamps which require lower voltage to produce the standard candle-power.

Loop System.—In order that all lamps on a circuit shall burn with equal brilliancy at all times, it is necessary that the resistance of the circuit from the generator to any lamp shall have a constant value, and be equal to the resistance through any other lamp. This is partly accomplished in the ordinary **tree** system of wiring, but is much better done in the **loop** system, in which the mains are run in the form of closed loops.



An ordinary loop is shown in Fig. 180, *a* and *b* representing the feeder and *c, c,* the mains with the lights taken off between them. An inspection of this loop will show that the distance the current has to flow from the + terminal to the − terminal for any one lamp is the same as for any other lamp, hence the resistance is the same and consequently the fall of potential is due to the same resistance, and all having the same voltage will burn with equal brilliancy.

This loop has the disadvantage of not furnishing current to all the lamps in case of a break in a main. If there were a break at *d* in the positive main, all the lights to the right of the fracture would be extinguished. This disadvantage does not exist in the next loop described, though it is not as perfect for equalizing the drop.

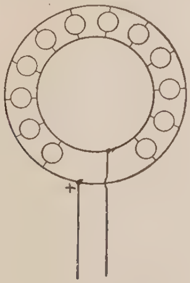


Fig. 181.
Loop Wiring.

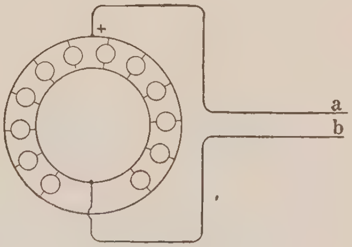


Fig. 182.—Closet Wiring.

In the loop shown in Fig. 181 it is seen that in the event of a fracture in either leg of the circuit, there will be no break in the continuity of the circuit and all lamps will still burn, and it would require two breaks in any one leg to extinguish a lamp. This is a very ordinary form of loop installed on shipboard, usually being provided with an interconnecting switch opposite the junction with feeder.

Still another modification of the loop system is shown in Fig. 182.

This is known as the **closet system**, but it does not adapt itself very readily for installation on board ship, though instances of its installation are known. It combines the advantages of both the other loops, and as a means of equalizing potential it is almost perfect.

Simple Parallel System.—Another system in use on a number of ships is the simple parallel system, as shown in Fig. 183.

The feeders are *a* and *b*, feeding the mains *c* and *d* from which are taken in simple parallel, the lights *e, e*. Every light is taken direct from the mains and that is the general rule, though in some cases, there are sub-mains from the principal mains, and lights taken from these sub-mains as though from the principal mains. To the right of the figure is shown a sub-main *g, h*, from *c, d* and the lights *e, e* are taken from this sub-main. In this system, the feeders are brought to a point where the mains will divide the current equally, as a rule feeding into the centers of the main. To this class of feeders is given the name **center feeders**. If the main is practically but a continuation of the feeder, as it is in isolated cases, it is called an **end feeder.**

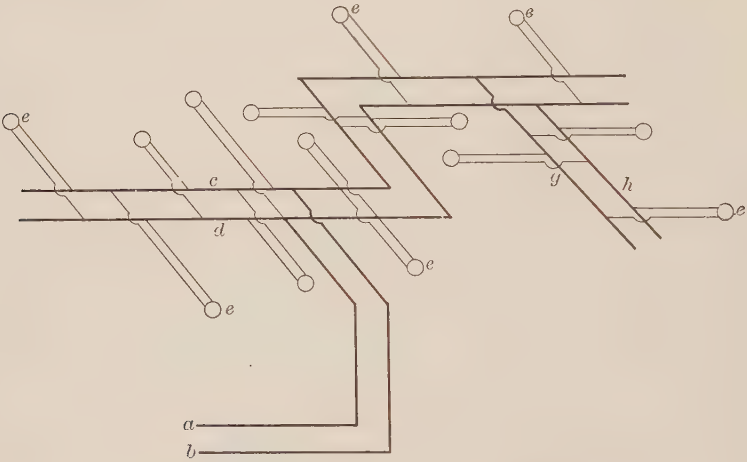


FIG. 183.—Parallel System of Wiring.

This system allows considerable drop along the length of main, but the conductors are made sufficiently large to reduce the drop to a small amount. It frequently happens that the best all-around result is obtained by a combination of the two systems. A feeder may feed two loops, with sub-mains taken from the loop in which the simple parallel system is adopted.

Loops should be resorted to wherever possible, for though it may take more wire in the mains it decreases to some extent the amount used in the branches, as well as equalizing the potential and current all around the circuit.

As an instance of the combination of the loop and simple systems as installed on board ship, Fig. 184 will show a circuit as installed on one of the gunboat class.

There are feeder boxes at *a, b, c,* and *d.* The main feeder from the switchboard comes direct to *a,* from which run sub-feeders to *b* and *c.* At *d* is a sub-main running aft. These loops are on different decks, the upper loop running entirely around the half deck, through offices, pantries, through and around the cabin. The lower loop makes a complete circuit around the wardroom, through the state rooms and wardroom country, the sub-main leading aft for lights in store rooms, and steering engine room. The sub-feeder supplying the lower loop runs up and down, and such a feeder is sometimes called a **riser.**

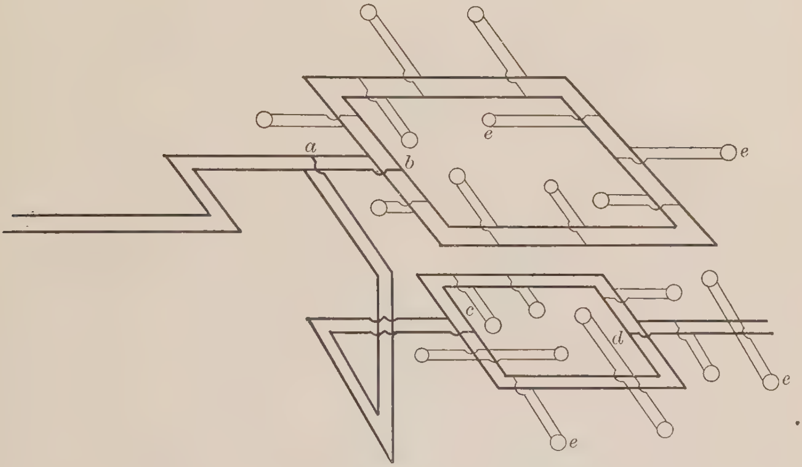


Fig. 184.—Parallel Loop System of Wiring.

This makes a well-balanced combination, in which though there is a drop of potential from the generator, there is not a difference of ½ volt measured in any part of the circuit.

Note.—It might be noted as a point in wiring that in connecting up a closed loop care must be taken to connect the proper terminals, otherwise instead of making two complete loops of the conductors, it may be connected as one long loop of single conductor, a serious combination for the fuses when the circuit is completed.

Whenever mains for the lighting circuits are led from feeders, it is done through standard junction boxes, having double-pole fuses which blow on the basis of 1 ampere per 500 circular mils of the main.

No more than two feeders are ever interconnected and no feeders are ever interconnected through their mains.

All outlets from the mains are fed by branch wires, fused. In offices and state rooms two outlets are usually installed on the same branch circuit. Each outlet for magazine lights is run from a separate junction box on the mains.

In the motor circuits when several mains lead from the same feeder at any one point, a small distributing panel is sometimes used, fitted with double-pole fuses, which blow at double the normal current of the motor.

System in Use on Later Battleships.—The general system of wiring now used in new ships is shown in Fig. 185.

Large-sized feeders are led from the distribution boards to the auxiliary distribution panels about the ship. These panels serve as distributing centers for the various lighting circuits. From them mains are run to junction boxes, from which sub-mains run to distribution boxes. From these distribution boxes branches lead to lighting fixtures. A maximum of five lights is allowed on each of these branches. To insure light in important compartments duplicate feeders are run from the forward and aft distribution boards.

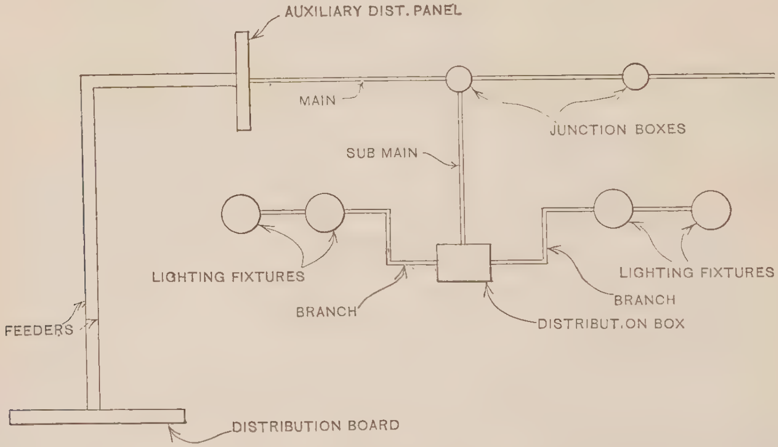


FIG. 185.—Later System of Distribution.

The same method of distribution to auxiliary panels is used for all but large motor circuits with the difference that the motors are fed from the auxiliary power panels direct. For large motors separate feeders are led from the distribution boards.

This method has superseded the loop system and the simple parallel system in ships recently built. On those systems a large number of lights were supplied from each main and damage to the main consequently threw out a larger number of lights. Also in the present method, with the distribution panels and boxes now in use, the lights in any locality can be turned on or off from the auxiliary distribution panel, or distribution boxes. This has been found a very desirable feature.

Marking of Feeders and Mains.—As a means of identification of the various feeders and mains installed in a ship, they are marked at certain intervals with letters and numbers according to a plan previously adopted. This is a great help during installation and a still greater help after the plant is completed. On the *Oklahoma* there are 138 feeders, supplying 218 mains. The plan described is followed in ships recently built.

(a) Electric conductors are marked by designating capital letters as follows:

Lighting feeders for battle service and search-light feeders	B
Lighting feeders for lighting service	L
All power feeders	P
All interior communication leads	I

(b) All battle, search-light, lighting and power feeders are numbered serially as B1, L2, P3, etc. Feeders from the forward distribution board are designated by odd numbers and those from the after board by even numbers.

(c) Mains and branches are given small letters, b, l, or p, preceded by the service number of the main or branch and followed by the serial number of the feeder. Thus the mains on feeder B2 would be 1b2, 2b2, 3b2, etc.

(d) All interior communication leads are marked with a capital I followed by the small circuit letters of the circuit.

Each conductor is tagged in each compartment with a brass tag, marked as outlined above.

Wiring Installation.

Conduit System.—The general requirements of wiring installation change from time to time, and the instructions given under this heading are those in use on most of the older ships.

All wires for feeders, mains and branches are installed in enameled steel conduit, except in wing passages, main generator and equalizer cables, and feeders from switchboard to dynamo-room bulkheads, which may be run in iron-strapped insulators, the wire in the insulators to be protected from mechanical injury by a metal covering of sheet or galvanized iron.

Thorough watertightness is observed for all leads into wiring appliances and fixtures, through all bulkheads leading into or out from a watertight compartment and through all decks.

Where conductors on lighting circuits are connected in fixtures and wiring appliances, the outer tape and braid on the ends of the conductors is to be removed, exposing the vulcanized rubber to within $\frac{1}{8}$ inch of the outside of the gland, and special care must be taken not to cut or injure the vulcanized rubber. When the tape and braid is removed for connecting up movable fixtures the braid ends shall be protected from fraying by whipping the ends of the braid and varnishing.

Watertightness through bulkheads or decks is secured by the use of stuffing boxes.

No feeders or mains are led overhead in places subject to great heat, or through or into coal bunkers if it can be avoided.

INSTALLATION OF CONDUIT.—The conduit containing the conductors is secured to the metal of the ship by stout straps which in the case of bulkheads are secured by machine screws. To attach conduit to beams, stiffeners and the like, a clamp is used of a design that does not require the beam to be drilled. All conduit should be continuous and where passing through watertight bulkheads, the conduit must be made watertight by standard stuffing tubes.

Where conduit passes through armor, a hole is first drilled and a long nipple inserted, watertightness secured by jam nuts on the nipple, each side of the armor, set up tight against the armor. The conduit is connected to the nipple on each side by a coupling or union.

Conduits for *magazines* are made of seamless drawn brass, and this is also required for all leads within 12 feet of the *standard compass.*

Both positive and negative legs of the same circuit are led in the same conduit for all conductors of and below 60,088 cm. All conductors above this size have a separate conduit for each leg, the lengths of conduit for the same circuit being kept as close together as possible.

Installation of Molding.—This is authorized in certain places, and when installed consists of three pieces; the backing strip, molding and capping.

The *backing strip,* secured first, is secured by brass machine screws, no screws coming under junction boxes, switches or receptacles and all screws are countersunk. *Molding* is secured by countersunk screws through the center wall to the backing strip. Both backing strip and molding is treated with white lead before being secured together. The capping strip is secured to the molding by round-head screws to the side walls of the molding.

All wire run through decks or bulkheads where molding is used is led through standard stuffing tubes, and when watertightness is not required, the wires are led through holes bushed with hard rubber.

All wiring accessories shall be separated from the metal of the ship by at least ¼ inch of clear solid wood, and they are never located over screws securing the backing in place. No double conductor or twin conductor is used with molding.

Armored Cable System.—An important change in the system of electrical installation on board ship is the replacing of the conduit installation by lead sheet and galvanized steel armored cable. The *Oklahoma* and *Nevada* are the first ships to have a "leaded and armored" installation. A brief description of the uses of the conductors and the rules governing their installation is given below:

CONDUCTORS.—The conductors used are of the three types that have been described, namely:

1. Plain (external covering of plain cotton braid).
2. Armored (external covering of galvanized steel armor).
3. Leaded and armored (lead sheath over taped conductor and this covered with a galvanized steel armor).

Plain conductors are used on leads in turret center columns, unless otherwise directed. Where plain conductors are used for leads in turret columns, leaded and armored conductors are led to the vicinity of the turret base casting where the two are connected by the employment of approved connection boxes. Special precautions are taken to maintain the watertight integrity and to reduce chafing of the leads to a minimum where conductors enter turret columns.

Plain conductors are also used for leads on certain portable fixtures, such as battle lanterns, cargo reflectors, portable 250-watt units, signal lanterns, watertight and non-watertight portables.

Armored conductors are used for leads on semi-portable fixtures, such as boom, steering, anchor, peak, blinker, truck and screened speed lights and all running lights.

Leaded and armored conductors are used for permanent leads throughout the ship unless exception be made in each particular case.

All main leads essential for battle efficiency are run below the protective deck.

Conductors are installed directly against decks and bulkheads by means of approved hangers.

All metal surfaces of the ship and plates to which conductors are to be secured are first red leaded and painted in accordance with hull specifications. Conductors running fore and aft pass through beams close up to the deck if practicable. Where there are a number of parallel leads or where it is necessary to avoid obstructions on bulkheads and decks, 5-pound plates are run under the beams (or frames) to form a path for the conductors. The conductors are strapped to the plates.

Where conductors pass through watertight decks or bulkheads, stuffing tubes are used, with the addition of red lead.

Where conductors pass through beams and non-watertight bulkheads, a clearance hole is drilled and the edges rounded off.

The penetration of decks, bulkheads and beams for wiring is in accordance with General Specifications for Building Ships.

Conductors are, after installation, treated with one coat of shellac and painted to match their surroundings. Wherever the red or black paint on the cable is marred or rubbed off during the process of installation, such portions of the cable are touched up with paint prior to shellacking.

Conductors passing through decks, in places where they are liable to mechanical injury, have a protection of conduit rising about 18 inches above the deck with a terminal tube at the top and a suitable bushing at the bottom end. The conduit passes through the steel deck and is made watertight with locknuts and washers and is made properly watertight also through wood decks. In special cases, where necessary, the conduit protection may be run higher than 18 inches.

Conductors are protected from mechanical injury by approved metal covering wherever deemed necessary. This covering may be watertight if required.

In order to comply with the requirement that all material in the vicinity of magnetic compasses be non-magnetic, conductors used in such locations have the outside armoring of *copper wire* instead of steel, and positive and negative leads are twisted together to neutralize the magnetic effects of the currents.

No electric conductors are led through magazines, shell rooms, mine rooms, torpedo warhead rooms, nor through rooms provided for the stowage of wet gun cotton, except where no other lead is possible. Whenever electric conductors of over 25 volts potential are run into or through magazines, such conductors are protected by watertight casing of 5-pound plating, with a suitable air space between the casing and conductors. In shell rooms, mine rooms, torpedo warhead rooms, or any room provided for the stowage of wet gun cotton, conductors are run on insulated hangers, but watertight casing is *not* required.

Where conductors are run into or through handling rooms, or ammunition passages, casings are not required.

All conductors are tagged in accordance with the latest standard requirements, both as to wire terminals for individual wires and tagging on the outside of conductor, after installation.

Conductors carrying spare wires in excess of standard requirements are provided in wiring passages, quarters, etc.

The Protection of Circuits.

Every precaution is taken in ship installation to guard against excessive currents, whether from short circuits, grounds, leaks or whatever cause. Every part of the installation is protected, each main generator, each circuit, each motor, or motor generator, each search or arc light and each individual incandescent lamp. There are main fuses or circuit breakers on the main switchboard to protect the generators, each lighting or power circuit is protected on the switchboard and each lamp on a circuit and each motor is separately protected. The fuses for the incandescent lamps are placed in the junction boxes from which the branches are led. In certain places like the engine or fire rooms, where the junction boxes would be likely to be installed in inaccessible places, they give way to distribution boxes, which are practically combinations of 10 or 12 junction boxes, all the branches leading from these boxes. They are installed in accessible places, where all the fuses can be readily examined or replaced. As an illustration of the protection given, that from a generator to a small portable ventilating fan may be cited. There is the main fuse or circuit breaker between the generator and main switchboard, then if there is a distribution board, there is a fuse between that and the main switchboard. The circuit on which the fan is installed is fused on the bus bar of the distribution board. At the junction box from which the fan leads there is a fuse. From the junction box the conductor leads to a receptacle which contains a fuse, and into this screws the plug from which leads the double conductor to the fan. This plug is also fused, making six fuses or circuit breakers in all between the generator and the fan, the safety appliances, of course, decreasing in size as the current falls off from that of the main generator, possibly 800 amperes, to that of the fan, .8 ampere.

CHAPTER XIII.

WIRING APPLIANCES AND FIXTURES.

WIRING APPLIANCES.

In general, **wiring appliances** are fittings used in making connections to conductors, making them watertight at decks, bulkheads, and fixtures. Some types include provision for cutting off or on lights. Those now standard are all of one general style, for use with electrical conductors of the three different standard types, viz., plain, armored, and leaded and armored. Standard wiring appliances are used for all new ships and for new installations and extensive repairs on older ships. For ordinary repairs on older ships the type of conduit and molding appliances, formerly standard are used.

All wiring appliances are made of cast composition, 80 to 88 per cent copper, 2 per cent tin, not more than 2 per cent lead and remainder zinc.

The following are the most important wiring appliances used:

Junction boxes,
Switches,
Switches and receptacles,
Receptacles,
Branch boxes,
Distribution boxes,
Terminal tubes, and
Stuffing tubes.

The descriptions given here are of the latest standard types.

Junction Boxes (Fig. 186).—These are round, tapped with four-way outlets, and fitted with a screw cover; the base of the interior fitting is made of an insulating material, similar to the commercial products, ebony, asbestos board, "Roxite," etc., with small copper bus-bar connections on top. The standard 3-ampere glass tube fuse is used when the junction box is installed on mains connecting branch leads, and standard link fuses are used when the junction box is installed on feeders.

Switches (Fig. 187).—Five-ampere, double-pole (single and double) and 25-ampere, double-pole are used. The 5-ampere, double-pole, single switch shown is provided with an interior fitting of insulating material on which are mounted the wire connections and springs. The switch control consists of a porcelain cam operating between two flat springs and moved by a switch handle located either in the side or top of the box. The 5-ampere, double-pole, double switch consists of two switches installed in one box. The 25-ampere, double-pole switch consists of a round box fitted with a handle and an interior fitting of the quick-break design. It is used when it is desired to control a number of lights such as on distribution boxes.

Receptacles (Fig. 188).—These are of the 5-ampere, single and double types. They consist of a rectangular-shaped box with an interior fitting of insulating material on which are mounted two contact springs forming the receptacle. In the cover is fitted a bushing with a screw cap through which is inserted the plug. The double receptacle is similar to the single receptacle with the addition of one receptacle.

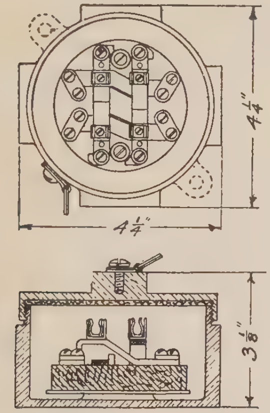


FIG. 186.
Branch Junction Box.

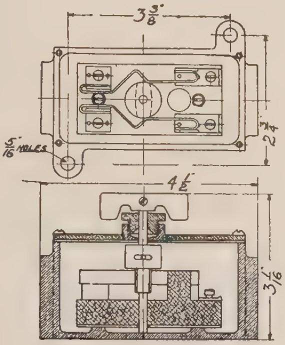


FIG. 187.
5-Ampere, Double-Pole
Snap Switch.

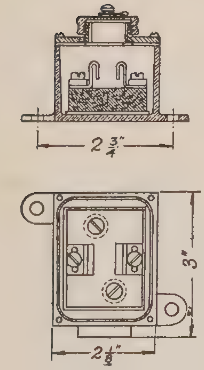


FIG. 188.
Single Receptacle.

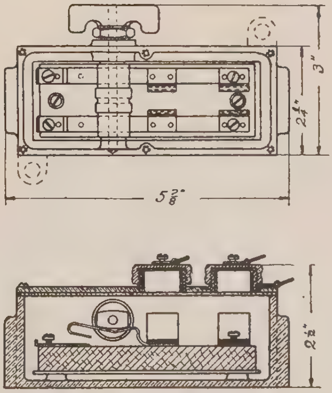


FIG. 189.
Switch and Double Receptacle.

Switches and Receptacles (Fig. 189).—These are 5-ampere, single and double, and 25-ampere, single. The 5-ampere switch and receptacle, single, is a rectangular-shaped box. On a base of insulating material are mounted switch contacts and contact springs as shown. The switch and the parts forming the receptacle are similar to those described above. The 5-ampere switch and receptacle, double, is similar to the 5-ampere switch and receptacle, single, except that one additional receptacle is provided. In both cases, as well as for the receptacle, the plug is wired with a double conductor and both terminals (positive and negative) are made on the single plug, which is made of insulating material. The 25-ampere switch and receptacle consist of a rectangular box, an interior fitting provided with a switch of the rotary type and two separate connections for the receptacle end. Two caps are provided in the cover. This is necessary since each leg of the circuit has a separate plug.

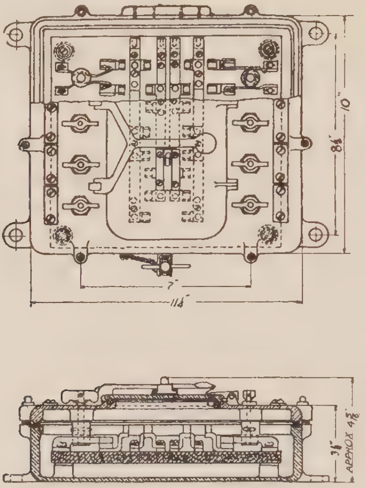


FIG. 190.
8-Way Double-Feeder
Distribution Box.

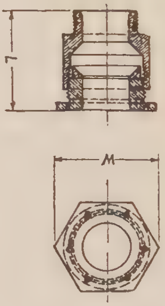


FIG. 191.
Terminal Tube.

Branch Boxes.—These boxes are used on branch leads where it is desired to make a connection without installing a fuse. There are two types, watertight and non-watertight, consisting of a round box, with a screw cover and fitted with a terminal block. This block is of an approved insulating material and provided with small bars and screws for connecting the wires.

Distribution Boxes (Fig. 190).—These boxes are used for centralizing the fuses for a number of branch leads and are in sizes for 4, 8 and 20 outlets. The boxes are fitted with a cover and made watertight by a gasket imbedded in the walls of the box. A hinged door with a snap catch is provided for examining or replacing fuses without removing the cover. These boxes are made with switches and without switches. The switches are of the standard, double-pole type and are used when it is desired to control all lights from a common point. The distribution box shown in Fig. 190 is the double-feeder type, which provides for mains being supplied from two different feeders. This type is principally used in the arrangement of magazine and turret lighting.

Terminal and Stuffing Boxes (Fig. 191).—These tubes are used on all electrical conductors led into appliances and fixtures, where watertightness is required. They consist of a composition tube, threaded at one end to fit the opening in the appliance and drilled and internally threaded at the other end to receive the gland ring and the gland nut. Flax packing is used. Where watertightness is required at decks and bulkheads, the stuffing tube is used, which is similar in construction to the terminal tube with the addition that washers (wrought iron) and nuts (composition) are used on both sides of the deck or bulkhead, thus insuring watertightness between the stuffing tube and deck or bulkhead.

Conduit.

On ships built prior to the *Oklahoma* and *Nevada,* wiring was installed in conduit.

Wiring appliances used for conduit are generally of the same types, and constructed for the same purposes, as those described above, but are constructed for connection to conduit, and differ in shape and details of construction.

Conduit consists of three types:

1. Steel, enameled.
2. Brass, enameled.
3. Flexible.

The **steel** is the most generally used, the principal use of the **brass** being in the vicinity of compasses. The **flexible** is used where watertightness is required and the fixture or apparatus supplied is portable.

The enameling is for protection of the conduit material.

The steel and brass conduits conform in their metal parts to the dimensions for standard pipe. The sizes used run from ½″ to 2″, in lengths of 10 feet for steel and 12 feet for brass.

The enamel is put on in not less than three coats, baked on, inside and out, and is not affected by moisture, acids, alkalies, or a temperature of 100° C. Sabin's baking enamel is frequently used.

FITTINGS.—The fittings for steel-enameled conduit are of steel, wrought, malleable or cast iron; for brass-enameled conduit, the fittings are of brass. Fittings of the forms usually employed for pipe fittings are used.

FLEXIBLE CONDUIT.—This is used in sizes from 1″ to 3″ inside measurement. It is made of rubber-lined hose, double covered.

Molding.

Wooden molding was used for the protection of conductors before the introduction of conduit and is found on some of the older ships.

Molding consists of three parts; that part containing the wire gutters is known as the **molding**, the part upon which the molding rests is called the **backing strip** and that which covers the molding is the **capping**.

When run over hardwood surfaces, molding is of the same material and finish as the surrounding woodwork. In all other cases, it is of thoroughly seasoned white pine, coated with white lead before being secured in place.

The backing strip is used to cover all rivet and bolt heads, nuts, etc., and to make a smooth surface for the molding.

Molding is made with one, two or three gutters.

LIGHTING FIXTURES.

Fixtures as a rule are watertight, although a small number of non-watertight fixtures are used. They are grouped as " regular fixtures " and "special fixtures." The principal types and their uses are described below.

Regular Fixtures.

Deck Fixtures.—These are direct lighting fixtures consisting of base, fitted with a globe and guard. The globes are of an elongated-bowl shape, made of clear plain glass and clear prismatic glass, both types being frosted on the inside. The fixtures are watertight. The guard is only used when the fixture is located where it is subject to breakage. They are used for general illumination throughout the vessel, except in officers' quarters. On destroyers this type of fixture is used for all locations, but in officers' quarters the prismatic globe is provided, while the plain globe is used elsewhere.

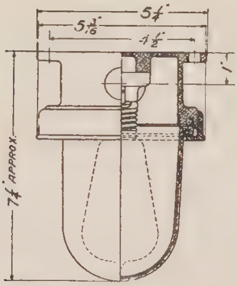


FIG. 192.
Deck Fixture.
Type H.

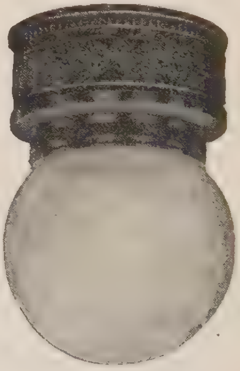


FIG. 193.
Ceiling Fixture, No. 1.

Bulkhead Fixtures.—These fixtures are similar to the deck fixtures, except that they are provided with side lugs instead of lugs on top, for installation on bulkheads. They are used especially in crew's spaces for night lights, installed near the deck, and are often mentioned as "night lights" and "hammock lights," the object being to provide light at companionways and hatches and on decks beneath hammocks without disturbing the crew.

Ceiling Fixture (Fig. 193).—This fixture is used principally in officers' quarters for general illumination and, as the name denotes, is installed under the deck. The base is of composition with a screw-threaded neck into which the globe fits. There are two types of globes used; both are spherical in shape, one of clear plain glass, and the other one of clear prismatic glass, both frosted on the inside. The advantage of the latter type is in the diffusion of the light rays.

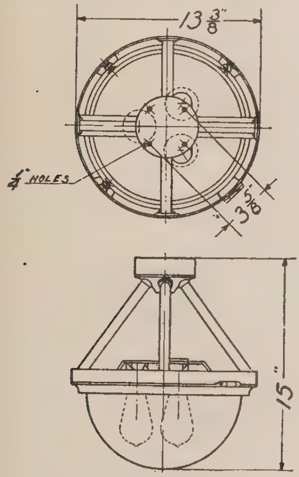


Fig. 194.
Hemispherical Ceiling Fixture. Type A.

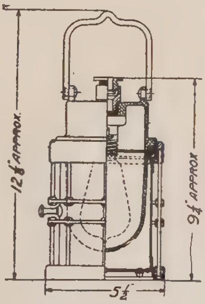


Fig. 195.
Portable Battle Lantern. Type I.

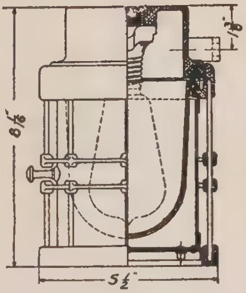


Fig. 196.
Fixed Battle Lantern. Type K.

Hemispherical Ceiling Fixture (Fig. 194).—This is a semi-indirect fixture, fitted with a prismatic bowl reflector of plain glass, frosted on the inside and illuminated by three lamps, usually 40-watt tungstens. Lighting is obtained by reflection from the top of the fixture (which is open) against the ceiling, and through the diffusion of prisms on the bowl. It is used for mess room and cabin lighting.

Bracket lights, desk lights and electroliers, non-watertight, are used for illumination in officers' quarters.

Battle Lanterns (Figs. 195 and 196).—There are two types, portable and fixed. The portable type is used in night action around guns and ammunition hoists. It is fitted with a metal shield so as to screen the light when required. The fixed type is used in passage ways, officers' and crew's quarters, and are installed about 2½ feet above the deck so as to throw the light down on the deck.

Deck Lantern.—The deck lantern is in all respects similar to the battle lantern, but is not fitted with the metal guard. It is used where open lights are required on the upper decks and bridges.

Portable, Watertight (Fig. 197).—This fixture is similar in general construction to the bulkhead and deck types, but is provided with a handle, and is without any lugs for securing. It is used for general portable lighting.

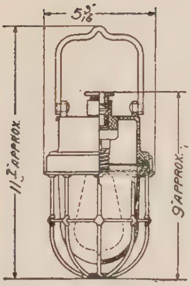


FIG. 197.
Watertight Portable.
Type H.

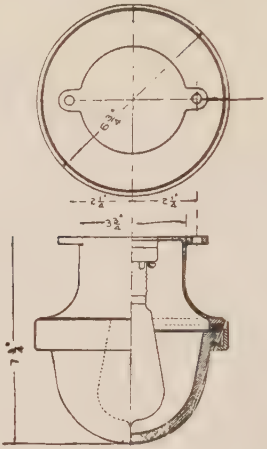


FIG. 198.
1-Light Magazine Fixture.
Type I.

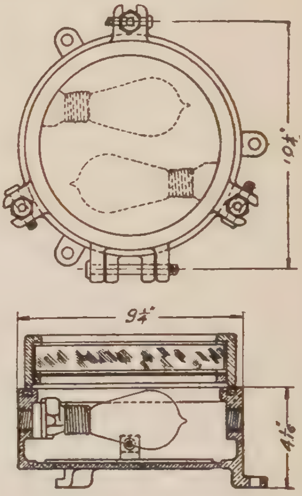


FIG. 199.
2-Light Magazine Fixture.
Type D.

Portable, Non-Watertight, Hooded.—This fixture is made up of a commercial metal shade or reflector and a waterproof socket, and is used around machines and in store rooms, where detail lighting is desired. With this fixture, the object to be seen is illuminated without any light shining in the eyes of the operator.

Magazine Fixtures (Figs. 198 and 199).—The **one-light** fixture consists of a composition base with a single lamp, and enclosed by a thick, semi-spherical globe of clear glass, frosted on the inside.

The **two-light** fixture consists of two lights mounted in a heavy composition box, with a thick, clear glass lens.

Turret Fixture (Fig. 200).—This fixture is essentially a watertight portable, mounted on a bracket with three-point suspension, held in place by means of three heavy coil springs which serve to take up shock. These fixtures are installed in turrets and in compartments in which powder and shell are handled.

100-Watt Units.—These fixtures are of the non-watertight type and consist of a steel, porcelain-lined reflector, fitted with a 100-watt lamp. They are used principally in machine and carpenter shops.

250-Watt Units (Fig. 201).—These fixtures are made both non-watertight and watertight, and are adapted for permanent or portable installations. They are made up of a composition base to which is secured a pan-shaped steel, porcelain-lined reflector. The watertight types are fitted with a globe. They are used for general illumination in engine rooms and on open decks. 250-watt tungsten lamps are used in them.

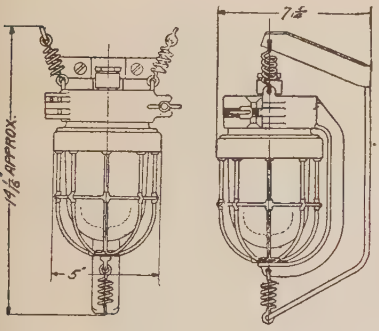


FIG. 200.
Front View. Side View.
Turret Lighting Fixture.

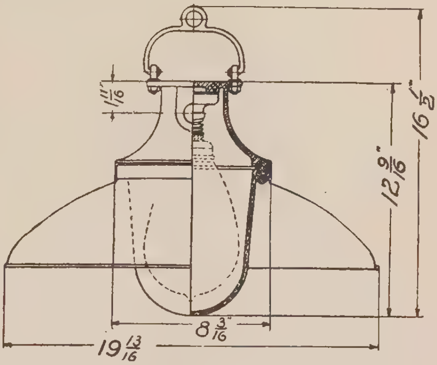


FIG. 201.
Watertight Lighting Unit. 250 Watt.
Type B. (Portable.)

500-Watt Units.—These fixtures are of non-watertight construction and are similar in construction to the 250-watt units. They are fitted with 500-watt nitrogen-filled lamps and are used on open decks.

1000-Watt Units.—These fixtures are of non-watertight construction and similar in construction to the 250-watt units. They are fitted with 1000-watt nitrogen-filled lamps, and are used on open decks in high positions to obtain "flood lighting." They are of special use in coaling ship and loading and unloading stores at night.

Special Fixtures and Lanterns.

Special fixtures and lanterns are each constructed for some specific purpose other than general illumination as follows:

Running lights.
Anchor lights.
Man-over-board and break-down lights.
Man-of-war lights.

Night-signal lantern.
Truck light.
Signal lantern.
Steering light.
Steering stand light.
Wake light.
Water-column light.
Portable tube blinker.
Blinker signal set.
Operating-room lights.

This list is added to as the necessity for additional types develops. The more important ones will be described.

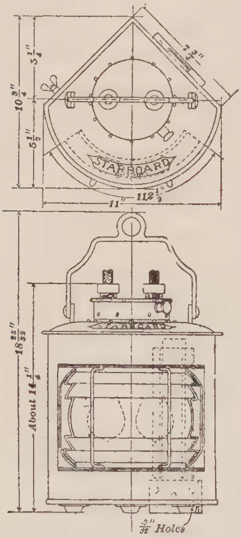

STARBOARD
$10\frac{3}{4}''$
$5\frac{1}{4}''$
$5\frac{1}{2}''$
$112\frac{1}{2}°$
11''
$18\frac{25}{32}''$
About $14\frac{1}{4}''$
$\frac{9}{32}''$ Holes

FIG. 202.
Standard Side Light.

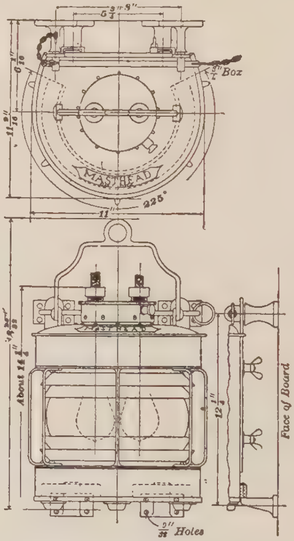

MASTHEAD
$\frac{3}{4}''$ Box
225°
11''
About $14\frac{1}{4}''$
$12\frac{1}{4}''$
Face of Board
$\frac{9}{32}''$ Holes

FIG. 203.
Standard Masthead Light.

Running Lights (Figs. 202 and 203).—These lights are constructed and placed to comply with the requirements of the "Rules for Preventing Collision." They are controlled from the bridge and are turned on or off simultaneously from one switch. They are exposed to the weather and the lamps are of particularly strong construction. The lenses are clear Fresnel lenses of cut glass. There are two lights in each lamp to provide a spare in case one burns out.

Anchor lights consist of the following:

(1) FORWARD ANCHOR LIGHT (Fig. 204).—This is similar to a deck fixture, inverted, and installed on top of the jack staff.

(2) AFTER ANCHOR LIGHT.—This is a portable fixture hung on the flag staff at a height lower than the forward anchor light.

(3) BOOM LIGHTS.—A portable, watertight, is used for this fixture when it is not practicable to use a deck fixture. It is installed on the end of the boat booms and propeller booms.

(4) PEAK LIGHTS OR FLAG LIGHTS (Fig. 205).—Peak lights consist of three, four or five white lights in a vertical line, spaced six feet apart and swung from the battle gaff or on the after side of the mainmast and are used to denote the absence of the commanding officer, or flag officer, and for "man-over-board" and "break-down" lights as described below.

(5) GANGWAY LIGHTS.—These lights are for illuminating the gangways and are controlled from the bridge. One type consists of a number of weatherproof sockets fitted with lamps strung along the rail of the accommodation ladder. Another type consists of a 100-watt unit installed on deck so that part of the light will shine on the ladder and deck and yet not shine in the eyes of persons on deck.

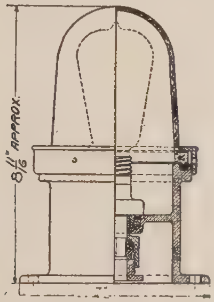


FIG. 204.
Anchor Light (for Steel Jack Staff).

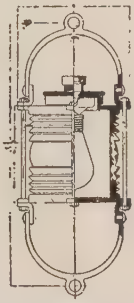


FIG. 205.
Peak Light.

Man-Over-Board and Break-Down Lights.—These consist of two red lights in the after part of the vessel, forming the two upper lanterns in the peak-light ladder, operated from the bridge.

Man-of-War Lights.—These consist of two white lights in the after part of the vessel. Two of the peak lights may be used for this purpose. They are controlled from the bridge.

The **night-signal lantern** (Fig. 206) is one of four used with the regular night-signaling installation. It consists of two composition castings, one at each end, containing the stuffing glands for the conductors, and a top and a bottom piece into which the castings are secured, held together by side rods.

Between the two end pieces are secured two 6-inch lenses with a diaphragm between them. The upper lens is red and the lower one is white.

The **truck light** is illustrated in Fig. 207. The lantern itself is very similar to that used for night signaling, and has the same size and style of lenses, the upper one red and the lower one white. It is supported on a heavy brass casting which fits on the mast truck. It is wired for a 32-candle-power lamp in each lens.

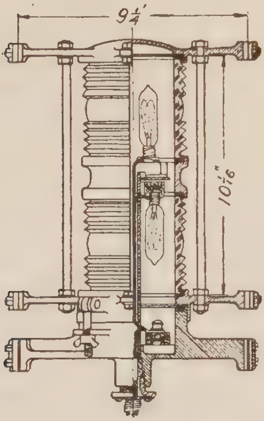


FIG. 206.
Night-Signal Lantern.

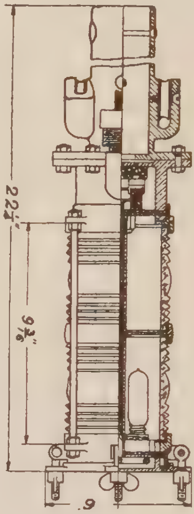


FIG. 207.
Truck Light.

CHAPTER XIV.

ELECTRICAL INTERIOR COMMUNICATION.

Wiring.—Interior-communication cable is used on all circuits except in special cases where standard twin conductor cable is used, and for telephones. For telephones special cable composed of twisted pairs is used. Leaded and armored cable is used for all permanent wiring and plain cable for portable leads.

All cables and wires for circuits used in action are kept below the water line as much as possible.

Wiring Appliances.—The standard forms of wiring appliances described in Chapter XIII are used in "Interior-Communication Wiring," and leads are made thoroughly watertight in the same manner described therein. In addition there are a few appliances used only in this system. These include cut-out switches, connection boxes, and different forms of push buttons.

CUT-OUT SWITCHES.—These are used to cut out of circuit such circuits as are used in ordinary times and which are wired with those that should be used in time of action. The idea is to cut out such exposed circuits not needed in action to prevent injury to them interfering with the needed action circuit. Action cut-out switches are located on switchboards in the central station (single-throw, multiple-pole, dependent upon circuits).

CONNECTION BOXES.—These are used to break the leads of wires to take off branches and to obviate the necessity of soldering or making joints; they provide for 5, 10, 20, 40 and 60 wire connections and are used in localities where most suitable for the purpose intended. They consist of watertight metal boxes fitted with covers set up by wing nuts against rubber gaskets or with a cap secured by counter-sunk screws. In the box each wire of the cable has a flat copper terminal soldered on, on which is stamped the serial number and letter of its individual circuit; the terminals are then connected together on a metal lug secured to a porcelain base, the terminals set up by screws. In one form of box the porcelain base is not used, the wires being spliced together and insulated.

PUSH BUTTONS.—Three types of push buttons are used. In all of them the circuit is normally open. When the buttons are pressed down, a spring is compressed and the contacts brought together.

Non-Watertight Push Buttons (Fig. 208).—This type is generally used in officers' quarters, and places not exposed to the weather.

Watertight Push Buttons (Fig. 209).—This type is used where watertightness is required. The whole push button is made watertight by a soft rubber gasket between the cap and cap ring, the cap and base, and under the base.

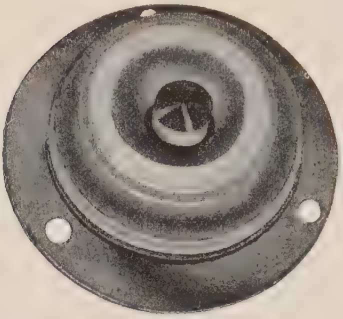


FIG. 208.
Non-Watertight Push Button.

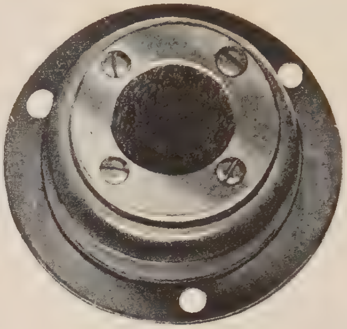


FIG. 209.
Watertight Push Button.

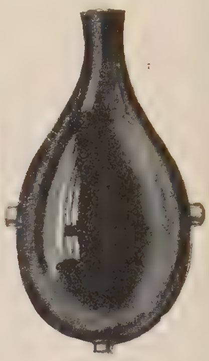


FIG. 210.
Pear Push Button.

Pear Push Buttons (Fig. 210).—There are three types, single, double and triple, with one, two or three contacts. The one shown is of the triple type.

Interior-Communication Switchboard.

The interior-communication circuits are fed from the interior-communication switchboard located in the interior-communication room.

The switchboard consists of two panels, the bus bars of which are supplied with current from three sources, viz.: from a 120-volt power feeder, from motor generators and from storage batteries. The power feeder and motor generator sources are used ordinarily, the batteries being for reserve purposes only.

On the panels are mounted the necessary bus bars and switches (see Fig. 211).

Each switch is fused and has a name plate, beneath which shows the designating letter and name of the circuit which it controls.

Mounted at the upper part of the panels are one ground-detector voltmeter, one 20-volt direct-current voltmeter and one 20-volt direct-current ammeter. Below the meters are located one 20-volt direct-current voltmeter switch, one ground-detector switch and one 20-volt ammeter switch. Four ground-detector lamps and two bracket fixtures are mounted across the top of the panels.

In the center of the panels a double-pole reverse-current circuit breaker is mounted. To the left a double-pole double-throw switch and to the right a four-pole double-throw switch are mounted. The left switch, when thrown

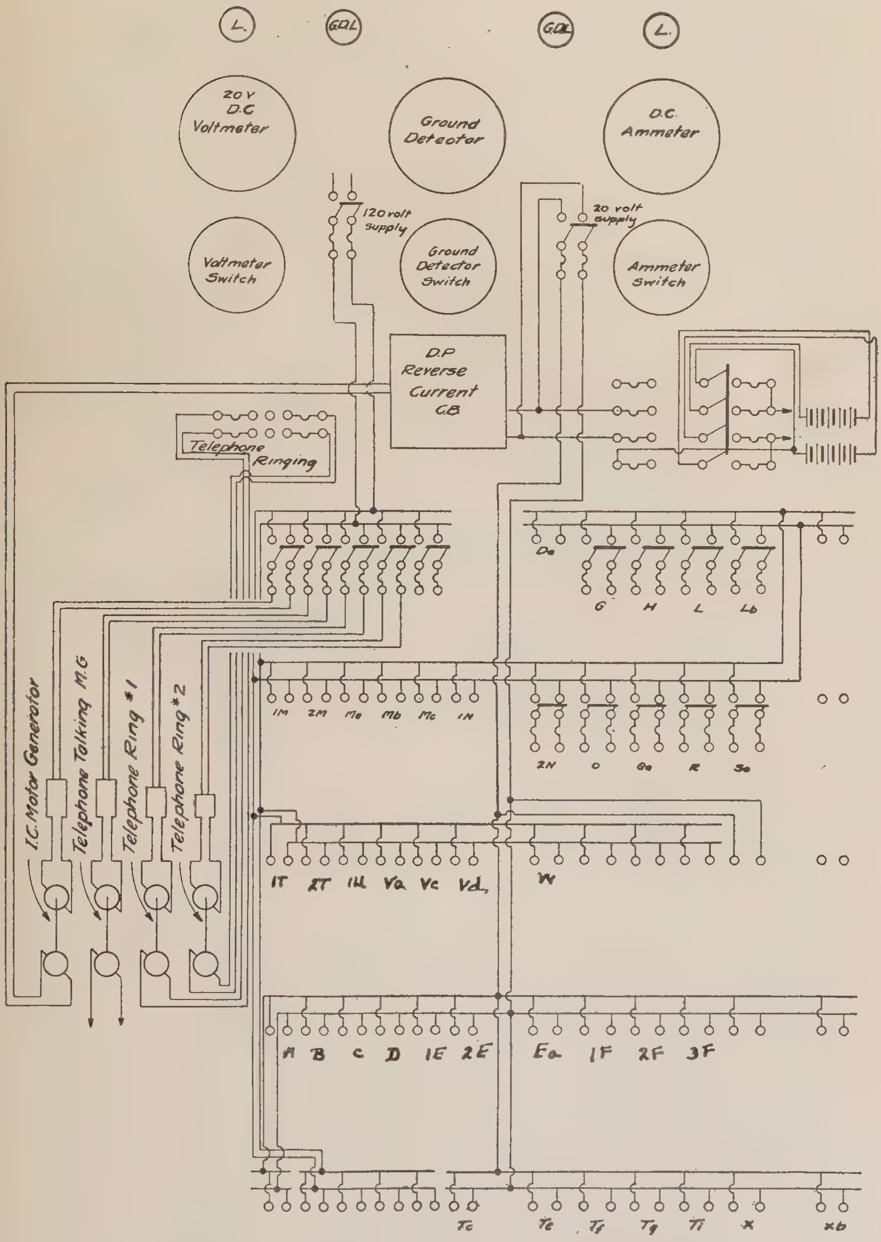

L.
G.D.L.
G.D.L.
L.
20 V D.C Voltmeter
Ground Detector
D.C. Ammeter
120 volt supply
20 volt supply
Voltmeter Switch
Ground Detector Switch
Ammeter Switch
D.P Reverse Current C.B
Telephone Ringing
I.C. Motor Generator
Telephone Talking M.G
Telephone Ring #1
Telephone Ring #2
Da
G
H
L
Lb
1M
2M
Ma
Mb
Mc
1N
2N
O
Ga
R
Sa
1T
2T
1U
Va
Vc
Vd
W
A
B
C
D
1E
2E
Ea
1F
2F
3F
Tc
Te
Tf
Tg
Ti
X
Xb

FIG. 211.—Interior-Communication Switchboard.

one way, controls the telephone ringing motor generator No. 1, and the other way No. 2.

The right-hand switch, when thrown one way, controls the supply to board from the storage batteries, when thrown the other way, connects the storage batteries to the charging panel.

Double-pole single-throw switches are mounted in five rows, 10 in the top row and 12 in the remaining rows. Circuits are taken off as indicated.

Two 50-ampere double-pole single-throw switches are mounted, one each side of the ground-detector switch. The one to the left controls the 120-volt supply and the one to the right the 20-volt supply.

The first five 25-ampere switches in the top row control the following machines:

Interior-communication motor generator.
Telephone-talking motor generator.
Telephone ringing motor generator No. 1.
Telephone ringing motor generator No. 2.
Warning-signal motor generator.

The latest specifications for battleships and battle cruisers call for but one ringing motor generator, the second set having been replaced by a hand-ringing magneto.

The following motor generators are used in connection with the interior-communication systems of battleships and battle cruisers:

One 2 kw. motor, 120 volts, direct current; generator, 25 volts, direct current, adjustable to 20—supplies all 20-volt direct-current interior-communication circuits.

One 1 kw. motor, 20 volts, direct current; generator, 120 volts, direct current—supplies telegraphs and indicators of steering circuits when ship's mains fail. The motor is run on a 20-volt interior-communication storage battery.

One $\frac{1}{2}$ kw. motor, 120 volts, direct current; generator, 12 to 20 volts, direct current—supplies all telephone circuits.

Two 25-watt motors, 120 volts, direct current; generator, 80 volts, $16\frac{2}{3}$ cycles, alternating current—for telephone ringing.

Two 2 kw. motors, 120 volts, direct current; generator, 125 volts, 60 cycles, alternating current—for gun firing.

One 2 kw. motor, 120 volts, direct current; generator, 125 volts, 60 cycles, alternating current—for warning signals.

Two motors, 120 volts, direct current; generator, 90 volts, 3-phase, alternating current—for master gyro compasses.

Two motors, 120 volts, direct current; generator, 22 volts, direct current—for azimuth motors of master gyro compass.

Interior-Communication Circuits.

The following is a tabulated list of all the circuits comprising the interior-communication system, lettered and numbered as indicated, and receiving power through the interior-communication switchboard, except where noted to the contrary:

Circuits A, B, C and D. Call-Bell System.—Between the various state rooms, offices, mess rooms, bath rooms, lavatories, pantries to orderlies and messenger calls. Voltage, 20.

Circuit Da. Docking Telegraph.—For use in transmitting orders when docking ship. Voltage, 120.

Circuit E. Voice Tube Call-Bell System.—For ship's service voice tubes only; exposed calls in circuit 1E and protected call in 2E. Voltage, 20.

Circuit Ea. Fire-Room Emergency Signal.—For signalling from fire room to engine room in case of emergency. Voltage, 20.

Circuit F. Fire Alarms.—To indicate excessive temperatures in magazines and bunkers.

Circuit Fa. Refrigerating-Room Temperature Indicator.—For indicating temperature of refrigerating rooms.

Circuit G. General Alarm Gong System.—Call to quarters. Voltage, 120.

Circuit H. Boat-Hour Gongs.— To indicate boat about to leave ship. Voltage, 120.

Circuits I and J. Ship's Service Telephone System for general use. Talking circuit 12 to 20 volts, direct current; ringing 80 volts, 16⅔ cycles, alternating current.

Circuits Ja to Jy. Fire-Control Telephone System for control of the battery. Voltage, 12 to 20.

Circuit K. Shaft-Revolution Indicator System.—Indicates R. P. M. of propellers' shafts. Circuits designated as 1K, 2K, etc., depending on number and arrangement. Voltage, variable, depending on speed of shaft. Not connected to interior-communication switchboard.

Circuit Ka. Secondary-Recording Counter System.—For shifting from A to B dial on Cummings' Recording Counter. Voltage, 120.

Circuit L. Steering-Telegraph System.—To transmit orders from conning to steering stations. Voltage, 120.

Circuit Lb. Steering-Emergency Signal System.—To indicate ship is to be steered from steering room. Voltage, 120.

Circuit Lc. Gyroscopic Compass System.—Special source of supply.

Circuit M. Engine-Revolution Telegraph System.—To indicate desired number of revolutions for engine room. Starboard and port designated as 1M, 2M. Voltage, 120.

Circuit Ma. Fire-Room Telegraph System.—To transmit orders from leading engine room to fire rooms. Voltage, 120.

Circuit Mb. Engine-Order Telegraph System.—To transmit orders from steering stations to engine room. Starboard and port systems designated as 1Mb and 2Mb. Voltage, 120.

Circuit Mc. Loud-Speaking Telephone System.—For passing the word about the decks. Voltage, 120.

Circuit 1N. Rudder Indicator System.—For indicating position of rudder. Voltage, 120.

Circuit 2N. Auxiliary-Rudder Indicator System.—For indicating general location of rudder. Voltage, 120.

Circuit O. Range and Deflection System.—For indicating range and deflection to fire-control stations and guns. Voltage, 120.

Circuit P. Gun-Firing System.—Used for firing all guns. Primary voltage, 120 alternating current, 60 cycles; secondary, 15 alternating current at gun.

Circuit Pb. Pyrometer Indicator.—For temperatures of smoke stacks. Not wired to interior-communication board.

Circuit Q. Warning Signal System.—Used as a warning to close all watertight doors and hatches. Voltage, 120 alternating current, 60 cycles.

Circuit Qa. Air-Lock Indicator System.—To prevent the opening of two doors of an air lock at the same time. Voltage, 120.

Circuit R. Turret Fire-Control Indicator System.—For controlling fire of main battery. Voltage, 120.

Circuit Sa. Smoke Telegraph System.—For indicating to fire rooms the nature of smoke desired. Voltage, 120.

Circuit Ss. Submarine Signaling System.—For transmitting and receiving audible signals through water. Voltage, dependent upon type. Not connected to interior-communication switchboard.

Circuit T. Torpedo Firing System.—For firing topedoes. Starboard and port designated by 1T and 2T. Voltage, 120.

Circuit Tc. Multiple-Turret Indicator System.—For indicating the train of each turret. Voltage, 20.

Circuit Te. Target-Turret Indicator System.—For indicating position of the target as regards the turret. Voltage, 20.

Circuit Tf. Target-Bearing System.—For indicating bearing of target. Voltage, 20.

Circuit Tg. Range-Finder Transmitting System.—For indicating range. Voltage, 20.

Circuit Ti. Automatic Dead-Reckoning Tracer System.—For tracing course of the ship. Voltage, 20.

Circuit 1U. Cease-Firing System, Main Battery.—To signal cease firing. Voltage, 120.

Circuit 2U. Cease-Firing System, Torpedo Defense.—Same as above.

Circuit Va. Torpedo-Defense Salvo System (Bells).—Used for firing signal for torpedo-defense guns. Voltage, 120.

Circuit Vc. Turret Salvo-Firing System (Bells).—Used for firing signal for turret guns. Voltage, 120.

Circuit Vd. Same as above except buzzers instead of bells.

Circuit W. Whistle Operator System.—For sounding main steam whistle. Voltage, 120.

Circuit X. Fuel Oil-Tank Indicator System.—For indicating when oil tanks are filled. Voltage, 20.

Circuit Xb. Drainage-Tank Indicator System.—For indicating when drainage tank is filled. Voltage, 20.

CALL BELLS, BUZZERS AND ANNUNCIATORS.

Call bells and buzzers are of watertight type only. The **bell** consists of an electromagnet and armature, with the usual make and break connections, mounted in a watertight composition box.

The mechanism is secured to the inside of the cover of the box. The bell proper is mounted on the cover of the box. The striker extends through the cover of the box and is made watertight by a stuffing box and gland. The armature is pivoted at one end and carries the striker at the pivoted end.

The leads are brought into the box through a stuffing box and gland. The box is made watertight by the cover screwing down on a rubber gasket.

The **watertight buzzer** is in all respects the same as the bell with the exception that the bell extension, the bell and bell striker are omitted.

Boat Hour Gong.—The boat hour-gong system consists of a contact maker located on the quarterdeck with 10″ single-stroke watertight gongs located in officers' quarters and in the several mess rooms.

Bell Wiring.

Electric bells or buzzers are installed on board ship for attracting attention for ordinary calls. Both require a complete two-wire circuit; from the source of current, to key or push button, and back to the source. No part of the ship may be used as part of the current path.

Typical Simple Bell Circuit.—A simple call-bell circuit is shown in Fig. 212.

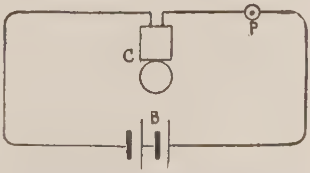


Fig. 212.—Bell Wiring.

B is the battery, C the bell and P the push button. The action of an ordinary vibrating bell is so well known as to require no particular mention. Closing the circuit by pressing P causes the circuit to be completed through the electromagnet of the bell, in which the make and break of the current causes the hammer to vibrate, producing a continuous ringing as long as the circuit is closed.

The object of the wiring of all bell circuits is to produce a definite result with the least expenditure of conductor, and a few examples of connection will be shown to illustrate the general principles.

To Ring Two or More Bells in Different Places from One Button.—This may be accomplished by connecting all the bells in parallel from the mains containing the battery and button, as shown in Fig. 213.

Pushing the button causes current to flow through all the branches containing the bells and each bell will have the same difference of potential at its terminals.

Or, the bells, button and battery may all be connected in series as shown by Fig. 214, provided certain modifications are made in the bells.

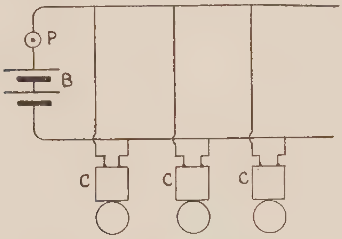


FIG. 213.—Bell Wiring.

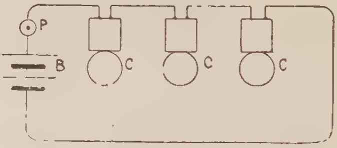


FIG. 214.—Bell Wiring.

In this arrangement all but one bell must be changed to a single-stroke bell, so that each impulse of current will produce only one movement of the hammer. The current is then interrupted by the vibrator of the remaining bell, the result being that all the bells will ring with full power. To cut out the circuit breakers on all but one bell it is only necessary to connect the ends of the magnet wires directly to the bell terminals.

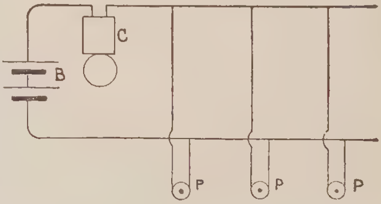


FIG. 215.—Bell Wiring.

To Ring One Bell from Two or More Places.—This may be accomplished by placing the buttons in the different places in parallel with the mains containing the battery and bell, as shown in Fig. 215.

Pushing each button completes a circuit, so the same bell may be rung from widely separated places.

Annunciator Systems.

These are but elaborations of the last examples of wiring, buttons being placed in widely separated places. When any one is pressed it closes the circuit and rings a bell at some convenient point, at the same time, by a mechanical or electrical device, indicating the location of the button.

A typical annunciator system is shown in Fig. 216.

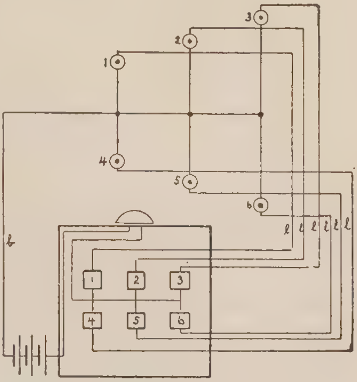


Fig. 216.—Annunciator Wiring.

In this, one side of each button is connected to a battery wire *b* and the other to a separate leading wire *l*, in communication with the drop on the annunciator corresponding to the button. There must be one wire from each button to the annunciator, but the other side may be connected to a common battery wire or to a common return, and it is in the connection to the common return where the saving in copper arises.

It is sometimes the practice, however, to run call supply mains throughout the length of the ship, especially if it be a small one, and from these mains are taken off different circuits as may be necessary; single-bell circuits, annunciator circuits, alarm circuits, etc. The following figure represents such an arrangement, being an example actually installed in a small vessel.

In Fig. 217 *a* and *b* represent the terminals of a double-pole double-throw switch, by which current for the mains is taken, either from the generator mains T and T′ or from the battery. R is a resistance introduced in the generator circuit to reduce the E. M. F. of the generator to that of the battery. 1, 2 and 3 represent push buttons on the upper deck, 1 connecting to the annunciator A in the wardroom, 2 to a boat bell C in the wardroom and 3 to an orderly's bell at D. Buttons 4 and 5 represent buttons in the wardroom state rooms connected to the annunciator and 6 in a room to call the orderly at D.

E, F, G and H represent alarm gongs connected in parallel between the mains through the contact points, E, F, G, H. These gongs are partly electrical and partly mechanical, electricity only playing the part of setting the mechanical gear in operation by which the gongs are continuously rung till the spring actuating the mechanism is run down. Only a momentary current is needed in each gong, the energizing of an electromagnet starting the mechanism. There are three gong pushes represented at 7, 8 and 9, in each of which there are four contact points connected with E, F, G and H. A small crank turns a switch connected at the center to one of the mains and it passes over the contact points. As it does so it makes the circuit complete through each gong, so they are each independently energized and their mechanism started. All four gongs can thus be started from any one of the buttons 7, 8 or 9, which may be widely separated from each other.

This figure is intended to show some of the ways of connecting up different circuits and in which ingenuity in saving wire is a prime factor. Of course,

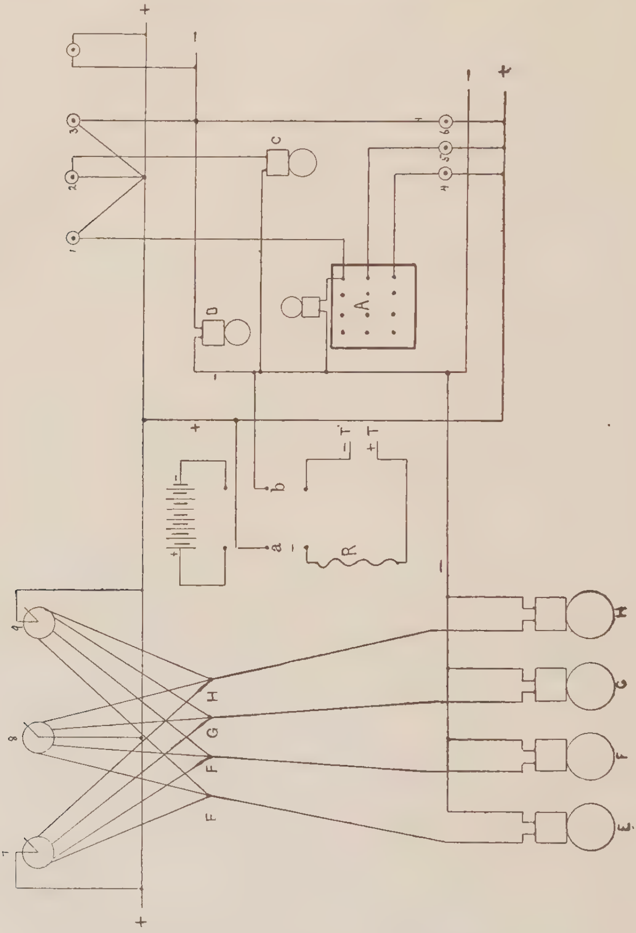


FIG. 217.—General Interior Wiring.

with the energized mains any number or kind of circuit may be taken off the principle of which is illustrated in these cases given.

Annunciators (Fig. 218).—There are two Navy standard types: the watertight annunciator for call-bell system and a special design of watertight annunciator used in the fire-alarm system. All are of the gravity-shutter drop type, so designed to prevent the shutter from being dropped by vibrations or gun-fire. The annunciator consists of a system of magnets and drops mounted in a watertight composition box. The box is hinged in two places, the front door opening to expose the magnets and the rear one opening to expose the contact springs to which the section leads are secured.

For each drop there is a single-pole electromagnet secured to a zinc plate. When a magnet is energized it attracts its armature, which releases a shutter that drops by its own weight. On the shutter is marked the name of the station at which the button is pressed.

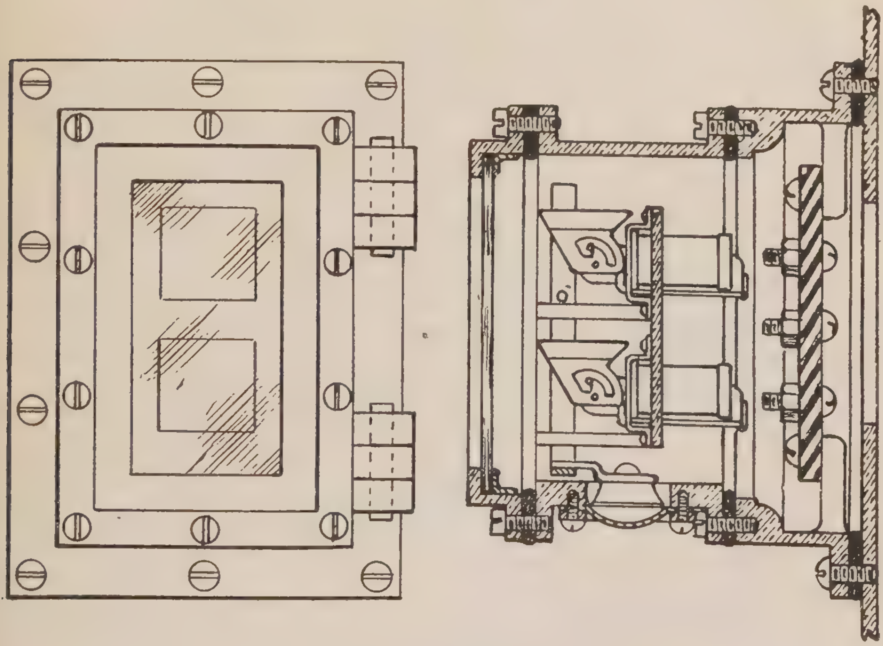


FIG. 218.—Annunciator.

All section wires are connected to metallic springs in the rear of box. From each spring, contact is made to one terminal of the magnet through a screw passing through the zinc plate and insulated therefrom. The other terminal of the magnet is secured to a screw in the zinc plate which forms part of the common return.

The fire-alarm annunciator is similar to that used with the call-bell system, but with the following exceptions:

Below the drops are arranged a set of switches, one being in the section lead to each magnet. These are normally kept closed, but when the circuit through any magnet is established it should be cut out to prevent the continuous ringing of the bell. Both terminals of the magnets are insulated from the zinc plate, one being connected as before, the other to one side of the switch, and the other side of the switch connected to the zinc plate which forms part of the common return.

Faults of Annunciator Systems.—Annunciators are made so that the front may be opened, exposing the electromagnets without disconnecting any of the wires. The faults most likely to occur are grounds or leaks caused by moisture in connection boxes or by corroded contacts. The annunciator should first be tested, then the push buttons and then the line. The annunciator is tested for leaks between the terminals of the wire leading from the bell and the different section spring contacts. If a leak is not found in a section, the push button should be examined, and if that is all right, the line should be examined in all the connection boxes.

The whole circuit can be tested for leaks by opening the circuit switch and testing across the line terminals with a magneto, and for a ground, test from each terminal to earth. If a ground is discovered at the circuit switch terminals, leave the switch open and test the annunciator between all the terminals and earth. If not found in first annunciator, leave it open and test the next, and so on. If the ground is not found in any of the section wires, then look for it on the battery wire leading to the bells in the connection boxes.

The dropping device in the annunciator may fail to work owing to the contact maker of the bell being so adjusted that the vibration is too rapid, so that the magnet does not have time to act. This can be remedied by the tension spring. The springs of the armature clips sometimes become weak, either not allowing the shutter to drop or not holding the shutter in place.

If any moisture makes its appearance in the annunciators, it should be at once dried out. This sometimes shows on the interior of the face.

TELEGRAPH AND INDICATOR CIRCUITS.

Telegraph and indicator circuits are installed to enable orders to be transmitted from one part of the ship to another. The transmitting apparatus operated by the sender is called the "transmitter," and the receiving apparatus is called the "indicator."

The system may include only one transmitter and one or a number of separate indicators, or a transmitter and indicator at each station, depending on the nature of the service required. A bell or gong or other method for calling attention to the indicator is generally used, and operated by the transmitter.

Selective Lamp Type.

In this type of telegraph the signals consist of lamps mounted in separate compartments in the instruments behind an opaque face plate with the orders or indications perforated in it.

In the transmitter an operating handle is moved to the position for the required signal, making contacts that send current through the lamp behind the corresponding signal or signals on the indicator. The handle is usually so wired that its movement actuates a bell or gong at the receiving station.

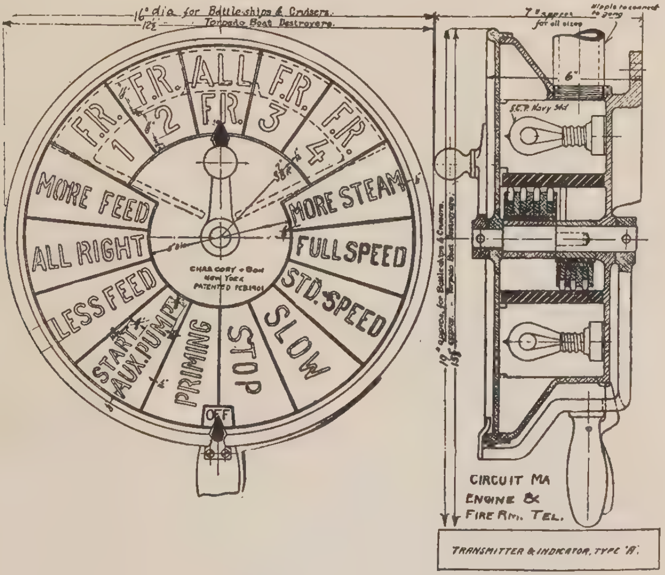

16" dia. for Battle-ships & Cruisers.
12½" Torpedo Boat Destroyers.
7" approx. for all sizes
Nipple to connect to gong
6"
S.E.P. Navy Std
F.R. 1
F.R. 2
ALL F.R.
F.R. 3
F.R. 4
MORE FEED
MORE STEAM
ALL RIGHT
FULL SPEED
LESS FEED
STD. SPEED
START AUX. PUMP
PRIMING
STOP
SLOW
OFF
CHAS. CORY & SON NEW YORK PATENTED FEB. 1901
CIRCUIT MA
ENGINE & FIRE RM. TEL.
TRANSMITTER & INDICATOR, TYPE 'A'.

FIG. 219.—Transmitter Indicator, Engine Room.

This type of instrument has been used for nearly all telegraph and indicator circuits, but has been superseded by other types for circuits where the signals to be transmitted have increased in number so much that this type would be too cumbersome and complicated.

Fire-Room Telegraph (Selective Lamp Type) (Figs. 219 and 220).—This system will be described as an example of the selective lamp type. In other systems of this type, there are differences in detail as separate transmitters and indicators, different shapes, automatic operation (as rudder indicators), but the general principles of operation and method of wiring are practically the same.

The system is for the purpose of transmitting orders from the leading engine room to the fire rooms and from any fire room to the engine room.

There is one telegraph located in the leading engine room and one in each of the fire rooms. Each of the instruments are combined transmitter indicators and in general are identical with each other, the only difference being that the engine-room instrument contains a switching device by means of which each or all of the fire rooms may be called. The fire-room instruments have no switching apparatus as they are designed to call the engine room only.

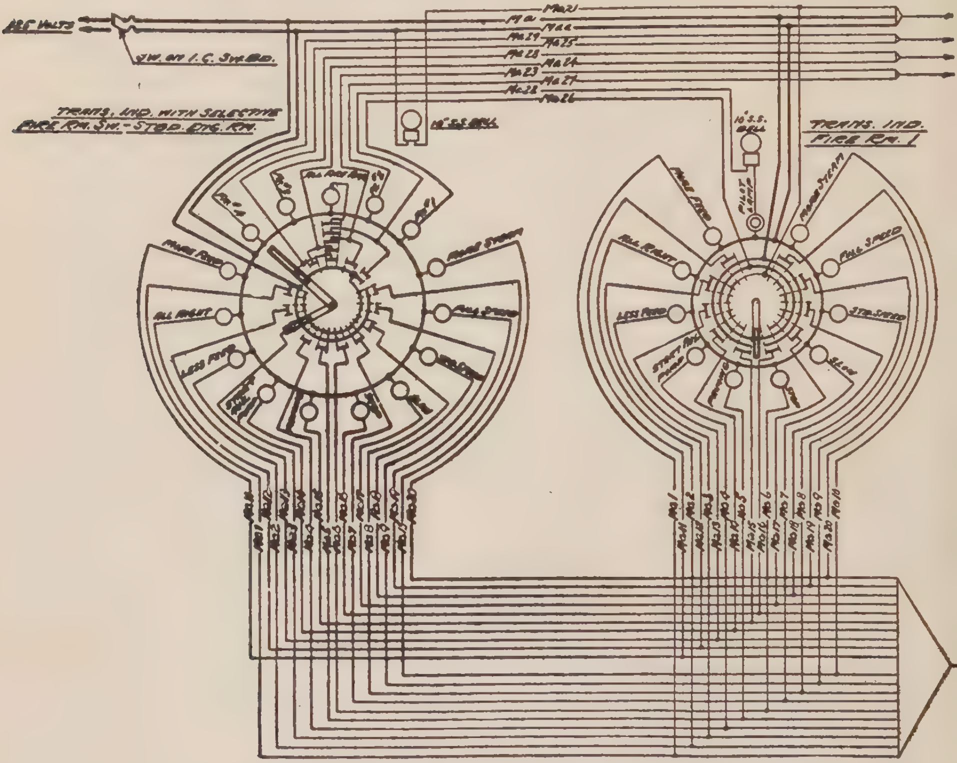

SW. ON I.C. SW. BD.
TRANS. IND. WITH SELECTIVE FIRE RM. SW.—STBD. ENG. RM.
10" S.S. BELL
10" S.S. BELL
TRANS. IND. FIRE RM. 1
PILOT LAMP
MORE STEAM
FULL SPEED
STD. SPEED
SLOW
LESS FIRE
ALL RIGHT
MORE FIRE

FIG. 220.—Wiring Diagram—Fire-Room Telegraph.

The signals consist of lamps mounted in the instruments behind the glass plates which cover orders or indications perforated in the face plate.

Attention is called in each room to the visual signal by means of a single-stroke gong, mounted on each instrument and so wired that for each signal given the gong will ring once.

The TRANSMITTER INDICATOR, ENGINE ROOM, consists of a cylindrical brass case which contains the lamps and mechanism and is fitted with a removable cover or dial on which the "order" indications are perforated.

One end of a metal cylinder, containing a contact band composed of layers of insulated compound alternated with brass segments, is secured to the back of the case.

A hand lever bearing a pointer is mounted at the back of case on a concentric spindle which acts as a bearing to a solid spindle, both spindles forming a continuous shaft through the center of the case and cylinder. Each shaft works independently of the other. A small handle and pointer is mounted on the end of solid spindle which projects through the dial.

A carriage, with projecting arms fitted with brushes, is mounted on each spindle.

When either of the handles is moved its spindle revolves, drawing the brushes over the inner surface of the band, thereby electrically connecting certain segments through the carriage.

The segments are electrically connected to the wiring of the instrument by means of binding posts mounted on the outer circumference of the cylinder.

There is no direct electrical connection between the contact wheels of the solid spindle and those of the other spindle, nor between the contact segments at the rear of the band and those at the front, as each spindle, with all it carries, is independent of the other.

Fifteen instrument lamps, one for each "order" indication on the dial, are mounted *radially* around the outer circumference of the cylinder. Five of these lamps are mounted in the upper part of the instrument and are wired to connect to contacts on the inner portion of contact band in the fire-room instruments and are for the purpose of distinguishing the fire room from which the order is repeated back.

To prevent any indication other than the one intended from being illuminated on the dial, a sheet of metal is inserted between each lamp.

In giving an order, the handle should be reciprocated slowly over several of the indications before being brought to rest at the indication desired, in order to attract attention at the fire-room instrument by giving several strokes of the gong.

The indications as shown are for a four fire-room system.

TRANSMITTER INDICATOR, FIRE ROOM, in general construction, is identical with that of the engine room, the difference being that small handle and pointer with indications are omitted. Besides the remaining 10 "order" indications the fire-room instruments are provided with a pilot lamp.

Operation.—Set the small handle (selective switch) of the engine-room instrument at the fire-room indication desired, then move the hand lever back and forth; this action rings the bell intermittently and pulsates the pilot lamp in the fire-room instrument, thus attracting attention.

Finally, lock the hand lever at the "order" indication determined on; this action stops the ringing of the bell and the pilot lamp burns steady until the lever is again moved.

On receipt of the order, the operator at the fire-room instrument moves his lever to the corresponding "order" indication. This action rings the engine-room instrument bell and lights up the lamp for that particular "order" and also the lamp representing the fire room which is repeating back.

If the order to be given includes all fire rooms, the operator in engine room turns the small handle to indication "**All F. R.**" this signal being wired in multiple with all fire rooms, the bell rings and the pilot lamp lights in each.

When each fire room acknowledges the receipt of the order, the engine-room bell will ring and the lamps indicating the "order" and the fire rooms will be lighted.

Voltmeter Type.

This type of instrument is a special type and has few uses except as **shaft-speed indicator**, to indicate by means of a pointer, moving over a graduated scale, the number of revolutions of the engine.

Shaft-Speed Indicator (Fig. 221).—This equipment has been devised to give an exact and instant check on the working of the main engines, both as to direction and number of revolutions. The necessary working parts are the **transmitter**, **regulator** and **indicator**.

The **transmitter** is a 2-phase alternating-current generator, having 12 fixed coils equally spaced around a circular frame and projecting inwards. Inside of these coils revolves six permanent magnets, by which is induced in the coils a 2-phase alternating current, as the coils are alternately connected and oppositely wound. The permanent magnets are secured to a shaft, which is caused to revolve at a speed varying with the speed of the engine shaft.

The **regulator** intervenes between the main shaft and the transmitter, and is driven by sprocket wheels on the shaft and regulator connected by chain. The transmitter is similarly driven by the regulator. The purpose of this regulator is to smooth out any slight variation of speed during each revolution of the shaft caused by the working of the engine, and which slight variation, if not dissipated, would cause the pointer of the indicator to vibrate. The regulator consists of the two sprocket gears, mounted on separate shafts, one inside the other, having a heavy spiral spring mounted within a case, the two ends of which are secured to the respective shafts. To cause this spring to better perform its function, a fly wheel is mounted on the shaft of the transmitter end, which, tending to revolve at a constant rate of speed, dampens the irregularities of the shaft, producing "dead beat" at the indicator.

The **indicators**, of which there may be any desired number, are mounted in convenient locations, as the bridge, conning-tower, central station and engine room. These are of the induction-type voltmeters, having a pointer passing over a graduated dial marked **ahead** and **back**. Extra precautions are taken to ensure watertightness of the indicators and they are so constructed that vibration and rolling of the ship will not affect the indication. The pointer stands normally at "0" and is there held by springs attached to the mechanism within the case.

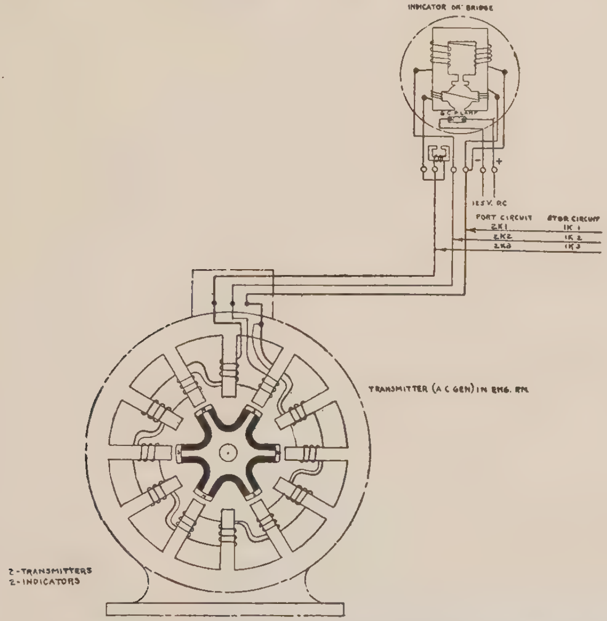


FIG. 221.—Diagram of Connections. Shaft-Revolution Indicator System.

The voltmeters are based on the principle of a revolving magnetic field produced by two out-of-phase alternating currents. A single-phase current would produce a pulsating field, but the 2-phase current produces a revolving field. A disc subjected to the inductive action of this field can be made to move under the influence of eddy currents induced in it. In the indicator are four coils, inside of which is an aluminum drum which is a part of the mechanism to which the pointer is attached. The 2-phase currents induce eddy currents in this drum, which cause it to revolve. As it tends to revolve, it is hampered by the above-mentioned springs, and is further retarded by the dampening effect of two permanent magnets. The force with which the drum tends to move and the distance it moves over is dependent on the E. M. F. developed by the transmitter, which, in turn, depends on its speed and that of the main engine shaft.

The ahead or back motion is accomplished by a change of phase at the transmitter, and a change in direction of rotation of the transmitter produces a corresponding change in the reading at the indicator.

There is a resistance in the indicator arranged to shunt the instrument, causing only a small amount of current to flow in the coils of the local instrument, thus producing greater accuracy of indications in case of change in resistance of the circuits.

In addition to the equipment, described above, there is a distribution box, or panel, containing regulating resistances. An inductively wound coil in this box may be so connected as to permit being thrown into circuit when an exposed instrument is out of circuit. This coil takes the place of the instrument cut out and is necessary to balance the resistance of the series circuit. There is a non-inductive resistance, calibrating rheostat, so arranged as to be conveniently accessible should it be found necessary to make a change in all the indicators at the same time. There are also two coils always in circuit and are so wired as to be in series with the entire circuit, one for each phase, and act inductively, balancing the current and checking stray currents.

Motor Type.

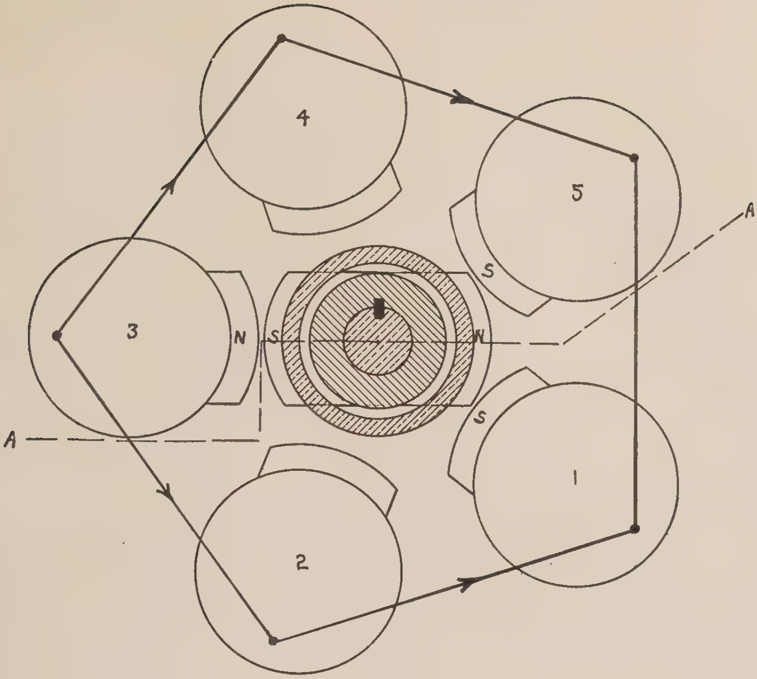
This type of instrument is generally used where it is desired to transmit numbers, as, the course indicator shows any number from 0 to 360. There are in the cover a number, usually three, "windows." Behind each window a dial is placed marked on its outer circumference with figures 0 to 9.

By suitable mechanism any desired figure on the dial may be brought behind its window. Thus with three dials graduated 0 to 9, numbers from 0 to 999 could be indicated. Instead of the figures, orders or signals may, of course, be put on the dials.

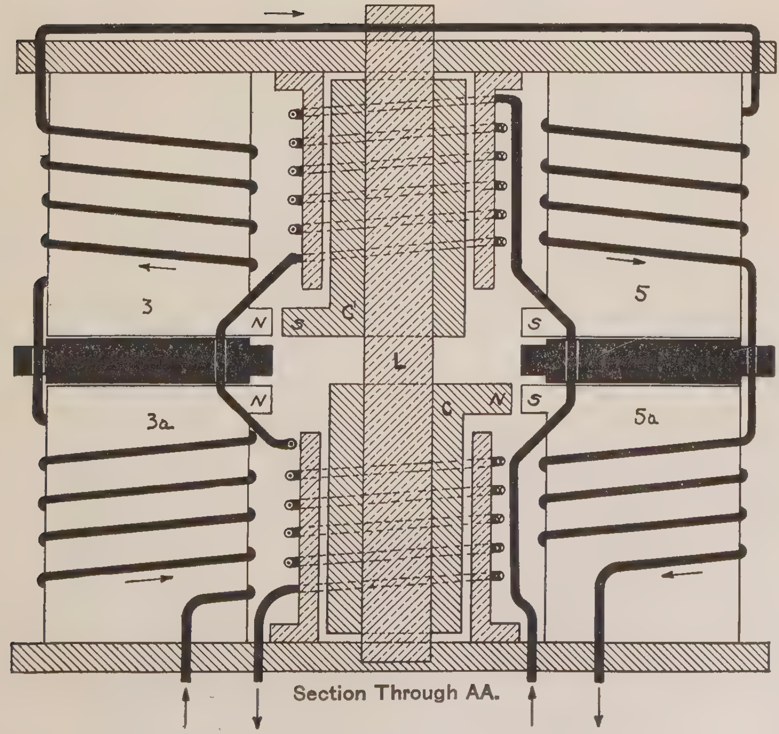
5-Pole Unit Indicator.—To actuate a dial with 10 indications, a 5-pole unit indicator is used.

Fig. 223 shows a developed wiring diagram of a 2- and 5-pole unit used in the motor-type revolution telegraph. This diagram serves to illustrate the principle of operation of all motor type of telegraph systems used aboard ship. Fig. 222 shows the construction of a 5-pole unit.

The 5-pole unit indicator consists of a double set of five electromagnets: 1, 1a; 2, 2a; 3, 3a; 4, 4a; 5, 5a; spaced equally around a double center


4
5
A
S
3
N
S
N
S
A
1
2

Plan.


3
5
N
S
C
S
L
N
C
N
S
3a
5a

Section Through AA.

FIG. 222.—5-Pole Unit Indicator (Dial Removed).

magnet C, C′, all shown in the developed diagram lettered as above. All magnets are permanently placed, but the cores of the center magnet C, C′, are mounted on the shaft L, having poles projecting outwardly at the inner ends as illustrated in Fig. 222. Shaft L is free to revolve and carries at its upper end the dial containing the indications to be shown. The central double magnet C, C′, is permanently energized as shown in the sketch whenever power is on the circuit, resulting in the cores being permanently polarized, C a north pole and C′ a south pole in the sketches. In the position of transmitter contacts shown in the figure, double magnets 5, 5a; 1, 1a; and 3, 3a, are energized, magnets 5 and 1 with south polarity and 3 with north polarity, the free poles of the center magnet assuming a certain position between the poles of 3 on the one side and 1 and 5 on the other. Ten different positions of the dial can be obtained.

The whole indicating unit is of rugged construction, easy of access and any single coil can be removed and renewed without disturbing the rest of the set.

3-Pole Unit Indicator.—This indicator is similar to the 5-pole indicator except that it actuates a dial with six indications.

2-Pole Unit Indicator.—This indicator consists of two electromagnets shown in the developed wiring diagram and electrically connected in the same general way as the 5-pole unit above described.

Between these magnets is a shaft to which is secured an armature. The shaft carries a dial at its outer end. When the magnets are energized, the armature is drawn into position and the corresponding figures on the dial show through a window in the cover the same as with the 5-pole unit.

When the circuit is opened through the magnets, the armature is automatically returned to normal position by the tension of a spring. There are but two figures on the dial of the 2-pole indicator, one for normal position and the other for active position.

The outer contact segments of developed transmitter diagram are connected to a single-stroke bell mounted outside the case on the pedestal and is so wired that the bell is rung for every change of indicating units.

Care of Units.—From the foregoing descriptions it will be seen that in the care and adjustment of the instruments, each unit is separate and any trouble may be located. In case of slight derangement, necessary repairs may be made, but in case of any serious trouble, the entire unit should be removed and a new unit installed.

Extreme changes in temperature are liable to cause "sweating" and should be avoided. The means provided for making the cases, shafts, etc., watertight, should be carefully looked after and in case of torn gaskets, etc., new ones should at once be installed.

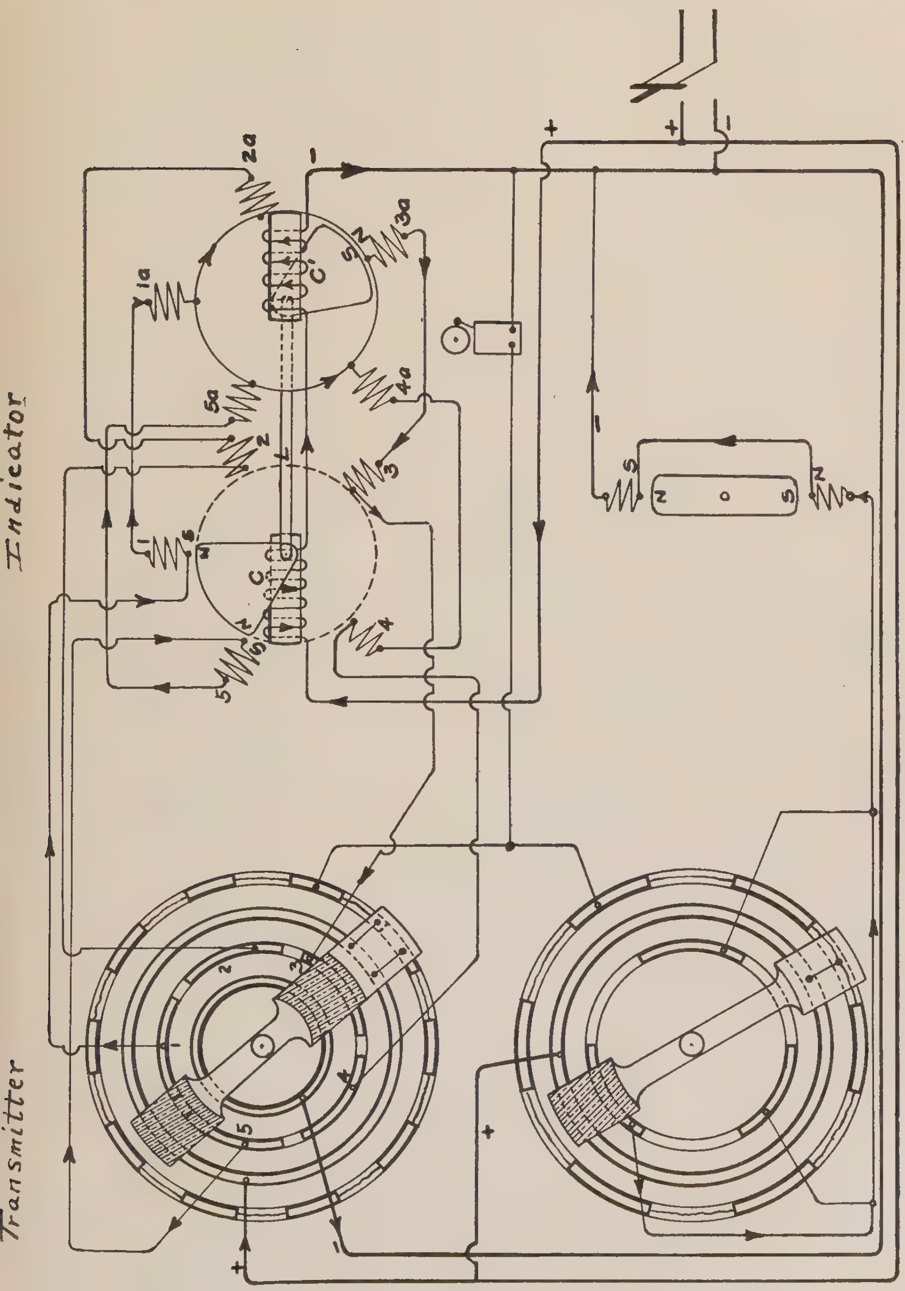

Indicator
Transmitter
1a
2a
3a
4a
5a
1
2
3
4
5
C
C'
N
S
+
-

FIG. 223.—Developed Wiring-Diagram Transmitter Indicator (Motor Type).

Transmitter Unit (Wiring Diagram, Fig. 223).—This unit consists of a set of insulated brass segments mounted within a cylinder and a revolving contact maker carrying brushes. The shaft of the contact maker carries a dial with the same markings as on the corresponding indicator, and extends through the cover. A handle is mounted on the outer end. When the handle is turned, the desired contacts are made by means of the contact maker, and the marking on the dial that shows through the window is the one that will be shown on the corresponding indicator. The connections can be followed in the wiring diagram.

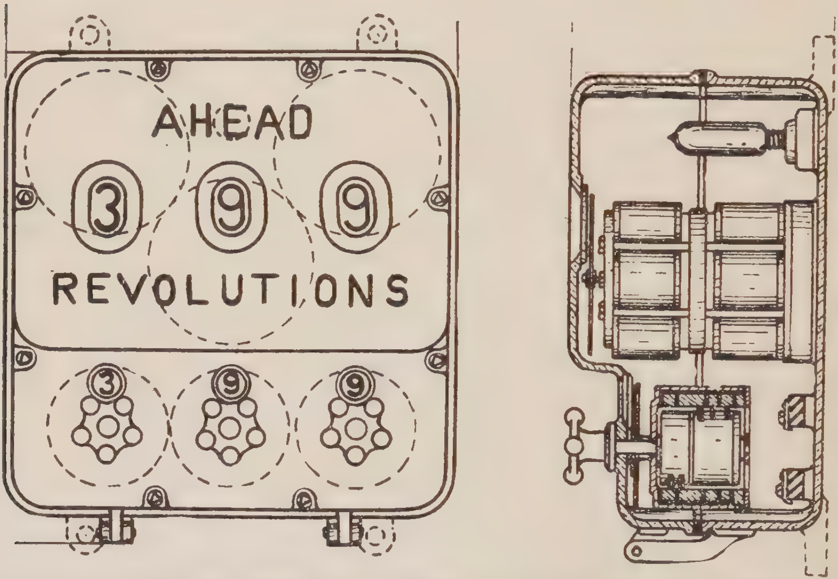


FIG. 224.—Combined Transmitter Indicator. Engine Revolution Telegraph.

Engine Revolution Telegraph (motor type, Fig. 224).—This telegraph will be described briefly to illustrate how the units are assembled and used. It consists of a combined indicator and transmitter arranged so that any number of revolutions up to 399 may be transmitted and repeated back, between the respective stations. All instruments are wired in parallel, but action cut-out (or transfer) switches are provided so that only two instruments can be in circuit together. They are operated from the 120-volt mains.

The case (Fig. 224) is of brass, with a watertight removable cover. It contains three transmitting units for transmitting hundreds, tens, and units, three indicating units—one three-pole for hundreds, one five-pole for tens, and one five-pole for units. Three 5-candle-power lamps are mounted behind the dial for illuminating them. The wire terminals are placed in the bottom to the various units by flexible cable. The transmitting units are secured to the cover, and the indicating units are secured to the base.

Other circuits in which this type of instrument is used in later ships are:

Course telegraph.
Electric steering telegraph.
Rudder indicator.
Docking telegraph.
Smoke Telegraph.

Simple Contact Type.

This type of telegraph circuit consists of one or more contact makers, located at different points, which, when moved to make contact, operate a gong or bell at some other location. In some cases an annunciator is installed at the indicating location, and the station from which the signal is made is indicated.

Steering Emergency Signal.—In this system there are three contact makers, located respectively at conning platform, conning-tower, central station. Any one of them when closed operates a gong in the steering room.

Fuel-Oil Tank System.—This system is designed to give audible and visual warning when an oil tank, which is being filled, is about 95 per cent full. This is accomplished by means of a contact maker, operated by a float in the oil tank, which is electrically connected to an annunciator and bell.

One contact maker is installed in each oil tank.

One side of the circuit is connected to one terminal of each of the contact makers, the other terminal of each contact maker is in multiple with one plug cut-out switch in each of the three annunciators.

Three annunciators are installed as follows: One in port engine room, one in starboard engine room and one near filling pipe.

A 3-inch watertight vibrating bell is installed near each annunciator.

A watertight relay is connected in series with the annunciator drops.

Drainage-Tank System is similar to the above except that a bell is used without annunciator.

Air-Lock Indicating System.—The purpose of this system is to furnish an indication at each air-lock door to show whether the other is opened or closed. A contact maker at each door when it is opened operates a bell and lamps at the other door. The circuits are supplied at each air lock directly from the battle lighting circuits.

MISCELLANEOUS.

A number of circuits for special purposes resemble in some respects those already described, but cannot be properly classed as coming under particular types.

Centrally Controlled General-Alarm System.

The general objects of the central control in connection with the general-alarm system are the great reduction in wire sizes to out-lying contact makers, the elimination of cumbersome contact makers and the placing of all mechanism in a convenient place where instant attention can be given it by the caretaker.

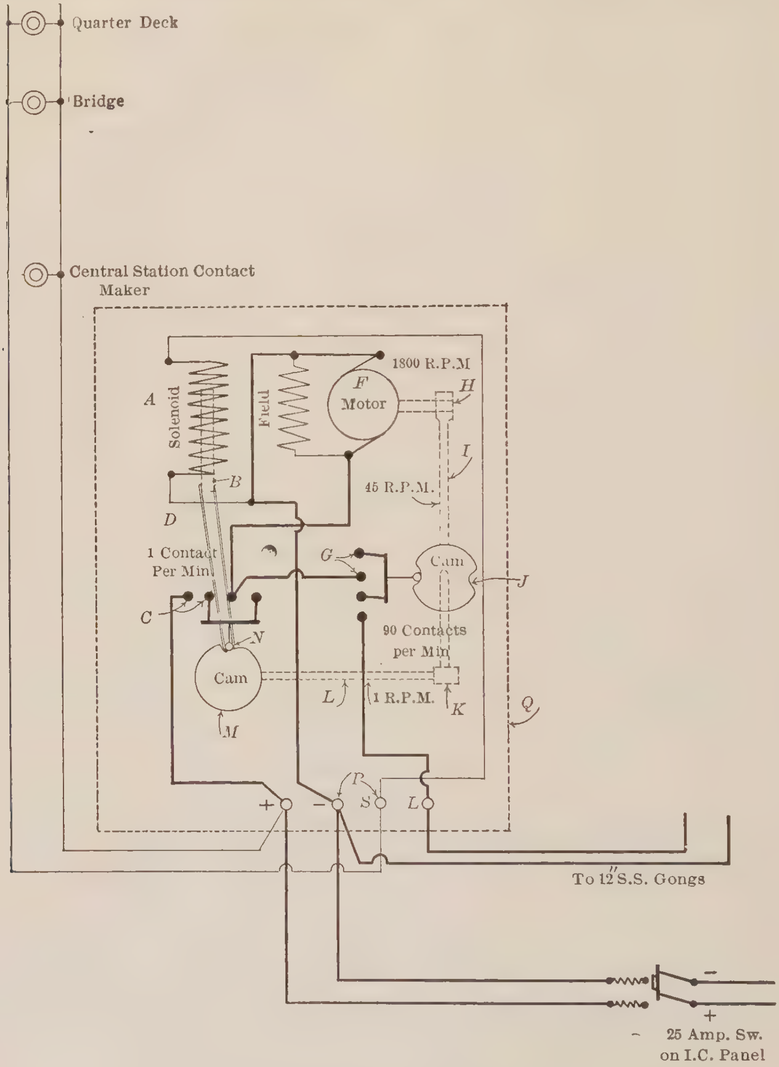

Quarter Deck
Bridge
Central Station Contact Maker
A
Solenoid
Field
F
Motor
1800 R.P.M
H
I
45 R.P.M.
B
D
1 Contact Per Min
G
Cam
J
C
N
90 Contacts per Min
Cam
L
1 R.P.M.
K
M
Q
P
+
−
S
L
To 12" S.S. Gongs
−
+
25 Amp. Sw. on I.C. Panel

FIG. 225.—Centrally Controlled General-Alarm System.

These objects are accomplished by the installation of the apparatus shown in Fig. 225 which gives the wiring of the time-controlled contact maker in detail as well as the out-lying points of control and the leads to the gongs.

If it is desired that a "general alarm" be sounded by the use of the above system, the procedure is as follows:

One of the small contact makers shown in Fig. 225, say in conning-tower, is operated; instantly, current is supplied to the solenoid A; armature B is actuated, which in turn closes contact C through the operation of a lever D on a crank arm E not shown in figure. Current is now supplied to the motor F and series contact G. Motor F at once attains a speed of 1800 R. P. M., which, through the worm gear H, causes the shaft I to revolve at 45 R. P. M. In the periphery of cam J are two slots so cut as to allow the actuating arm of contact maker G to fall into each one once for each revolution, thus opening the circuit to the gongs 90 times per minute. The shaft I is further geared through worm K to shaft L which revolves 1 R. P. M. This shaft carries cam M, which has one notch cut in its outer circumference, and on the completion of its one revolution the extension N of crank E falls into this notch. The solenoid having already been de-energized and the circuit to the motor having been broken at contact C by the above action, the apparatus will remain inactive till the outlying contact makers are again operated.

Contacts C and G are supplied with both metal and carbon contacts. The carbons always "break" last on the contact being opened, so as to take the "spark" or inductive charge when the gong circuit is broken.

Binding posts P for connecting line wires are provided at the bottom of the slate base Q.

Warning Howler.

This is a device for making an unusual sound, as a warning to those in the neighborhood that watertight doors are to be closed, and is used as a substitute for the warning whistle.

Its action will be understood by reference to Fig. 226, which shows a wiring diagram of the operating circuits. A small shunt motor M is connected by gearing to two peculiar-shaped switches S and a commutator C. Each switch S consists of two flat pieces of spring brass, which press against a cam-shaped piece, shown in section to the left. This piece is covered with a conducting metal with an insulating section against which the spring pieces rest when the device is inoperative, as shown in section. The commutator C is a simple commutator for changing the direction of the current which flows through the coils M and M′. D is a diaphragm, which vibrates rapidly, due to the rapidly changing current in the coils, and its vibration gives rise to an unusual sound, which is intensified by the horn H.

To operate it is only necessary to close the main-line switch, and press one of the push buttons B. Current then flows from the line through the push button to the armature and field and to the other side of the line. As soon as the motor commences to revolve, it turns the cam against which the springs press at a slow speed and also the commutator C at a high rate of speed. As soon as the springs press against the conductor of the cam, current flows from the line through the two left-hand spring contacts, then through the motor. Contact on the cam switch remains until it has made one complete revolution when the springs drop from the cam on the insulating section and the circuit is broken and the motor stops.

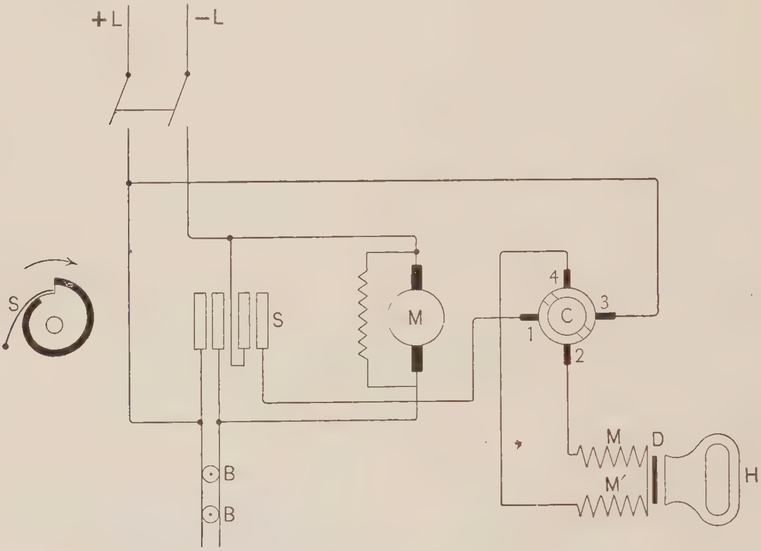


FIG. 226.—Wiring Diagram of Warning Howler. Chas Cory & Son.

When the motor is turning, the commutator C is revolving very rapidly and changes the current flowing through M and M′. Considering any one position, as that shown, current flows through the + line, through 3 to 4, around M and M′ in an anticlockwise direction to 2 and 1, through the two right-hand spring contacts of the cam switch to the − line. At another instant the segments of the commutator have interchanged places, when current flows through 3 to 2, around M and M′ in a clockwise direction to 4 and 1 through the switch S to the − line.

In starting it is necessary to keep the push button pressed long enough to allow the spring contact pieces to make contact on S, when the whole device is operative and the push button can be released. After one revolution of the cam, to make it operative again, one of the push buttons must be pressed. These buttons are all in parallel and may be located anywhere in the ship.

Fire-Alarm System.

The fire-alarm system, as its name signifies, is designed to give an alarm whenever a compartment becomes heated to a degree that is not considered safe, or when a fire breaks out in any compartment.

Coal bunkers, magazines and store rooms are all within this system of protection. An elementary diagram is shown in Fig. 227.

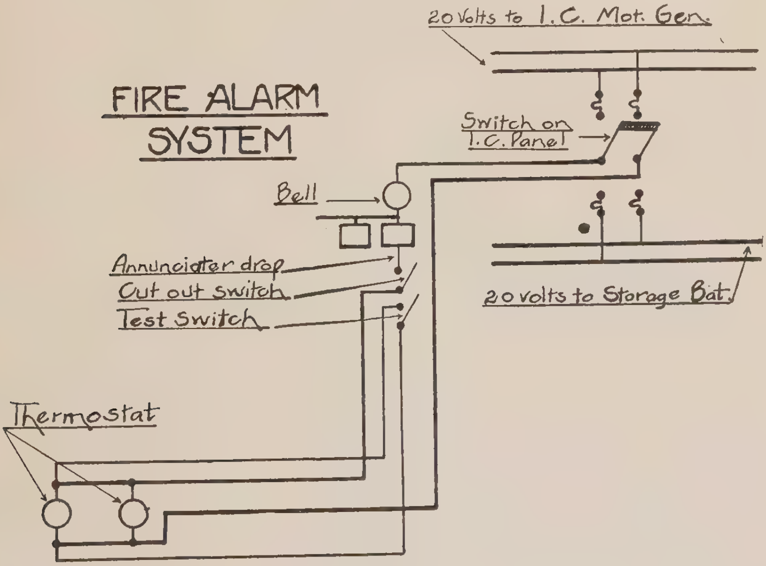

20 Volts to I.C. Mot. Gen.
FIRE ALARM SYSTEM
Switch on I.C. Panel
Bell
Annunciator drop
Cut out switch
Test Switch
20 volts to Storage Bat.
Thermostat

FIG. 227.

The apparatus consists of thermostats so arranged as to make electric contact at some predetermined degree of temperature; and two annunciators, one each for the starboard and port side of the ship.

Annunciators.—The fire-alarm annunciator is described on pp. 323 and 324.

Current is supplied from the interior-communication panel at a pressure of 20 volts. The cut-out switches are normally closed and the test switch open. With the E. M. F. of 20 volts on the feed wires and the above condition as to switches existing, the only open circuit in each line is at the thermostat, therefore should the thermostat make contact the alarm is given at the annunciator in the central station.

The test push button is used to try each line for working condition. If, when test button is pushed in, the drop for the respective compartment falls, the line is shown to be in circuit throughout with the thermostat in place. The thermostat may or may not be in working order, and to test this, water, at a slightly higher temperature than that at which the thermostat is set, may be applied to the thermostat.

Concentrated brine should not be used under any circumstances.

No adjustment of the thermostat is practicable.

If too much heat is applied the mercury in the tube will rise to the expanded portion and will not return to its normal position.

The automatic alarm feature of the thermometer, in case of a breakage, has been made operative by casing the bulb of the tube with a copper jacket and using this jacket as one side of the circuit.

A test should be conducted periodically for the working condition of the line by trying the test push buttons.

Grounds and leaks may be tested for in the usual manner.

If grounds, etc., are found on the positive leg, search must be conducted through the connection boxes, always commencing at the connection panel which is a part of the annunciator case.

Mercurial Thermostat (see Fig. 228).—These are of the mercury contact type and consist essentially of the following parts: Interior fittings, box and outer guard.

INTERIOR FITTINGS.—A thermometer is passed through two soft rubber gaskets, fitted respectively in each end of a brass nickel-plated stuffing tube 1 inch long and threaded for its entire length on the outside.

The thermometer is of the stem type, with column working in vacuum. The mercury reservoir is approximately of the same diameter as the stem. A supplemental reservoir is provided just above the main one, so that in the event of the latter breaking, there will be sufficient mercury in the former to rise and bridge the contact.

Two platinum contacts, upper and lower, are sealed in glass.

The upper contact is secured at the point of rated temperature; the lower is permanently in contact with the mercury. When the mercury expands to reach the upper contact the circuit is closed, and the alarm is indicated by the bell and drop at the annunciator.

The present standard rated temperatures are: 105° F. for magazine, 150° F. for store rooms, 212° F. for coal bunkers.

The thermometers are constructed to stand temperatures of 50° F. above their rated temperature without breaking.

A standard copper conductor, covered with impregnated cotton, is soldered to each of thermometer contacts and to the free end of each conductor, a

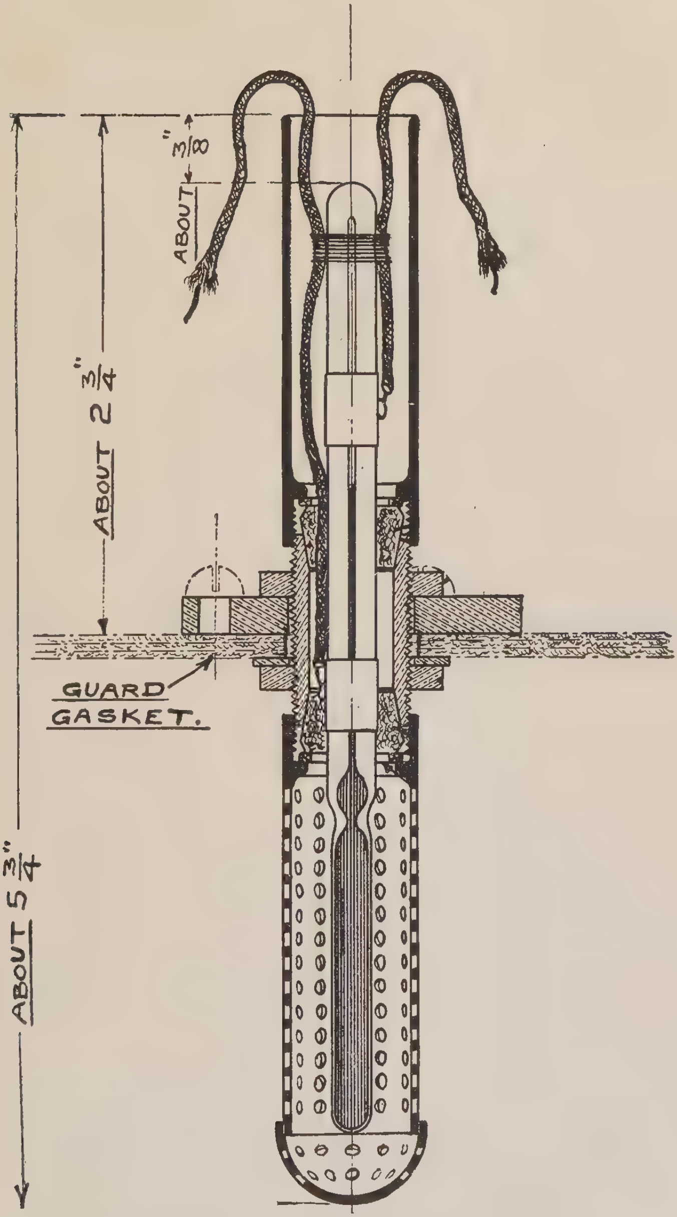

ABOUT 3/8"
ABOUT 2 3/4"
ABOUT 5 3/4"
GUARD
GASKET.

FIG. 228.—Mercurial Thermostat.

terminal is soldered. The conductors are seized to the thermometer near the top, with linen thread in order to take up the strain.

As a means of protection, the thermometer is enclosed by an upper and lower guard.

The upper guard is a brass, nickel-plated cylinder with one end tapped to receive the upper end of stuffing tube on the thermometer and the other end left open as an outlet for the conductors.

The lower guard is a brass cylinder, perforated and its upper end is tapped to receive the lower part of the stuffing tube; the lower end of the cylinder is fitted with a perforated cap. This guard is also nickel-plated. Both guards are shouldered to act as glands on the stuffing tube.

The type of box used in magazines is of composition metal cast in two sections. The section which protects the upper part of the thermostat and conductors is L-shaped, flanged, and is installed inside the magazine, being secured to the other section by tapped bolts which pass through the magazine bulkhead; this type of box not being adapted for bolting to the deck. The other section or terminal box, is installed outside the magazine and is of composition metal, cylindrical in shape, flanged and drilled for bolting to the inside section, the joint being rendered watertight by a canvas gasket which is soaked in linseed oil and painted with thick red lead. A connecting passage between the two sections of box is provided by drilling a hole through the magazine bulkhead and inserting a hard, rubber-lined, brass insulating tube, which is secured in place by a brass nut on each side of the bulkhead.

The thermometer leads pass through this tube and are connected to the terminals in terminal box.

The terminal box is bossed at opposite points on its periphery.

OUTER GUARD.—This is a casting of composition metal, cast in the form of a cage; the top is flanged and has three lugs by means of which the guard is secured to the bottom opening of the box.

The circular plate on the thermometer is secured through the guard gasket to the guard flange; thus the upper part of the interior fitting and the conductors are protected by the box, and the lower part of interior fitting by the outer guard.

Mechanical Thermostat.—This type depends on the expansion in length of a metal rod when it becomes heated. The active portion of the mechanical thermostat is a coiled spring, which, when heated with one end held fast, increases in length, and in so doing the free end turns.

The coil is a right-hand composite steel and brass spring of 7½ turns, composed of steel inside, ⅜″ wide and .014″ thick and brass outside .034″ thick brazed together. As a protection from corrosion the springs are well tinned. The top of the spring is free and to it is secured a brass contact arm, and as the free end of the coil moves it carries this contact arm and with sufficient increase in length due to heat, the arm moves far enough to bring up against a terminal to which the leading wire to the annunciator is secured. The lower end of the spring is held fast by being screwed into a spindle which runs up through the inside of the coil and secured to the casting by which the thermostat is bolted in place. The other leading wire is secured to a terminal on the casting and the circuit is completed through the coil.

The terminal with which the bent arm on the free end of the spring makes contact is adjustable as to the distance the arm has to move to make contact by means of a set screw and as the expansion depends on the temperature, this distance can be regulated for a given temperature.

Thermostats differ in type according to their location. For bunkers the whole mechanism is enclosed in a watertight case except sometimes when they are placed overhead when the spring may be protected by a perforated metal guard. For store rooms the only protection necessary is that due to ordinary moisture and the greater area of the spring exposed to the heated air the better. The type for magazine is wholly enclosed so that the spark due to break of contact cannot come into direct contact with any inflammable gases that may be held in the magazine.

Temperature Indicator System for Refrigerating Rooms.

This system provides a means of reading and thereby maintaining the proper temperature of the air in the refrigerating rooms. The system consists of a thermometer inside and an indicator outside of each refrigerating room, and an indicator in the paymaster's office.

Electrical Resistance Thermometers.—Many electrical conductors change in resistance with change of temperature in a perfectly definite manner. The coefficient of increase of resistance of most pure metals is about .004 per degree Centigrade, between 0° and 100° C. This means that a conductor of one-ohm resistance will increase its resistance by .004 of an ohm for each degree Centigrade change of temperature between 0° and 100° C. Such a change of resistance can be most accurately measured and in consequence the change in temperature may be readily calculated. This is a far larger change than the percentage change in the ordinary mercurial thermometer, for mercury has a coefficient of expansion of .00018.

A convenient way of measuring the increased resistance due to change of temperature is to make use of a slide-wire bridge or Wheatstone bridge in which all the arms have approximately the same resistance as that of the thermometer resistance. Fig. 229 shows the connections for measuring the resistance of one or more resistances which are led to the same bridge.

The connections of battery, galvanometer and resistances r, r_1, r_2 and l form a slide-wire bridge to which the thermometers T1, T2, T3, etc., may be connected. The resistances r, $r1$ and $r2$ should be about equal and equal to the thermometer resistance at a mean temperature. A balance is obtained by moving the contact c along the arm l until such a point is reached that the galvanometer shows no deflection. The resistance l is such that it will take care of the variation of resistance of the thermometer.

In the actually constructed instrument l is made in the form of a circular wire and the contact arm is in the form of a pointer, which travels over a scale. This scale is graduated to read directly in degrees when used with a thermometer of a particular resistance and temperature coefficient. The resistance may be directly measured and the temperature taken from a previously plotted curve.

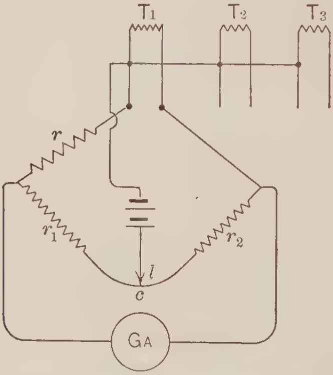


FIG. 229.—Connections for Measuring Resistance of Electric Thermometers.

The arrangement of connections shown does not compensate for changes in the resistance of the leads, but under ordinary conditions this does not cause an error of more than .1 per cent.

BULBS.—A form of resistance, or bulb, suitable for such temperatures as are likely to be found on ship board, is composed of pure platinum wire or nickel wire, silk insulated, wound in the form of a long skein on a light frame of micanite, encased in a brass tube filled with paraffin. The leading wires are lead covered, which are soldered to the resistance winding terminals, and the lead covering of the wires is soldered to the brass tube to prevent the entrance of moisture.

The resistance of such a bulb should be high, from 80 to 90 ohms, so that changes in the resistance of the leading wires will be negligible.

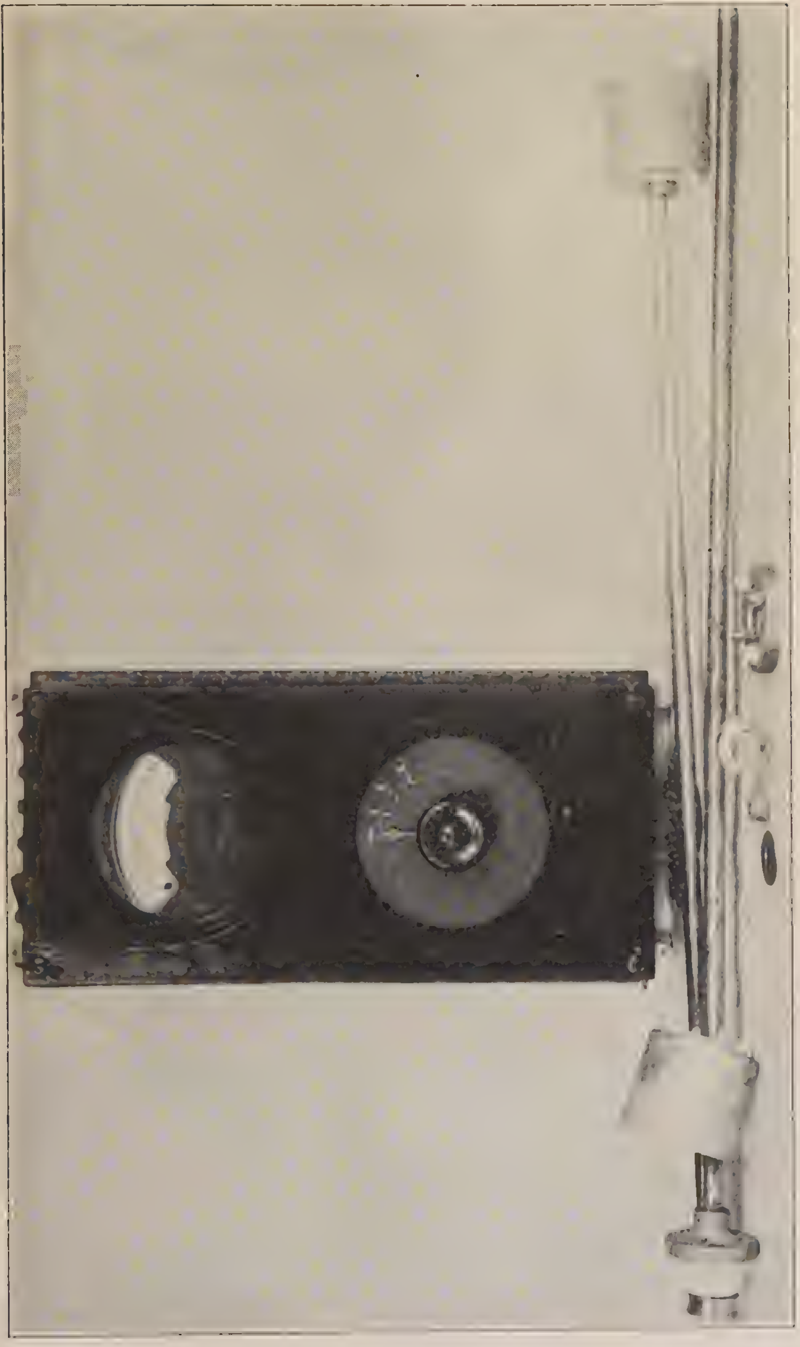


FIG. 230.—Pyrometer Indicator.

Pyrometer Indicator System (Fig. 230).

This system indicates the temperature of the waste gases in the smoke stacks, and consists of two thermo-couples, an indicator and a selective switch. A thermo-couple is installed in the base of each smoke stack, each couple being electrically connected to the indicator in engineer's office. Fig. 231 shows an elementary diagram of connections.

The operation of this system is thermo-electric, no outside source of energy being required as the thermo-couples are entirely self-generating, due to the fact that when two dissimilar metals are connected and the junction heated, a low voltage is generated which varies with the change of temperature.

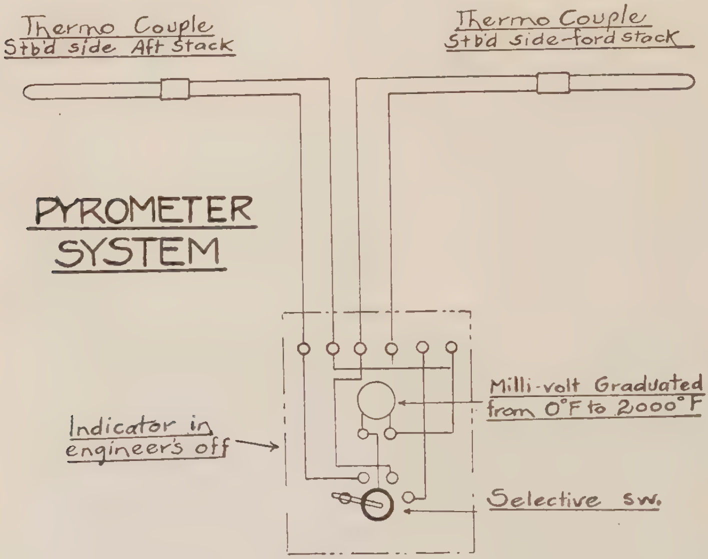

Thermo Couple
Stb'd side Aft Stack
Thermo Couple
Stb'd side-ford stack
PYROMETER SYSTEM
Milli-volt Graduated from 0°F to 2000°F
Indicator in engineer's off
Selective sw.

FIG. 231.

THERMO-COUPLE.—Owing to the severe conditions under which this system operates, a thermo-couple, made of the baser metals, is used, the couple being encased in a steel shell. As an additional protection the steel shell is given a thorough coating of graphite composition once a week.

The free ends of the "couple" connect to a porcelain receptacle secured in the open end of the steel shell. A circular case of aluminum alloy encloses this receptacle and the open end of the shell; the case is provided with a screw cover which has a hole in its center for the reception of the plug and cable which connects the "couple" with the indicator.

INDICATOR AND SELECTIVE SWITCH.—The indicator, selective switch and binding posts with wires are mounted on a board base which has a removable metal cover. A window is set in the cover to permit reading the indicator dial.

The indicator consists of a millivoltmeter having a scale graduated in degrees F. from 0 to 2000.

Below the indicator is the selective switch, by means of which any one of the thermo-couples can be connected to the indicator.

The binding posts are mounted on the head of the board.

When cleaning the uptakes and stacks, the thermo-couples can be removed.

Fire Timing Device.

This is an arrangement for calling attention by sound and exhibiting a visual signal at stated intervals of time, in order that the fires of a boiler may be regularly fed.

In general it consists of a transmitter and an indicator. The transmitter contains the driving mechanism for the circuit maker and the operating circuits, and the indicator contains the mechanism for producing the sound and the visual signals.

The **indicator** contains an electromagnet A, Fig. 232, which is energized at regular intervals of time. When energized its bell-crank armature B is attracted and its other end strikes a gong G, giving out a loud sound. The face of the indicator is covered by a circular disc, which fits over the three studs shown at C, which are secured to a small wheel, which is turned by the levers D whenever the electromagnet is energized. This disc carries a larger disc in which numbers are cut near the circumference. These numbers correspond to the furnace numbers, and each time the gong sounds a new number is brought under the hole in the cover (shown dotted), and is illuminated by two small lamps, LL.

The **transmitter** contains a small shunt motor M, which drives through proper gearing a flat disc, which drives another flat disc by means of a friction roller. These are not shown. This second disc drives the contact maker CM, which closes an electric circuit twice in each revolution.

At the bottom is shown a row of switches, one for each indicator, the blades of these switches being of the same polarity, one side feeding the electromagnet in the indicator, the other the two lamps. Half of these switches are wired to connect to starboard boilers, the other half to port boilers.

Analysis of Wiring Diagram.—There are two terminal blocks, L and L′, one for + potential, the other for − potential. The circuit for the motor, with its shunt field, is plainly indicated, and leads directly from terminal L1 through motor and field to terminal L′1.

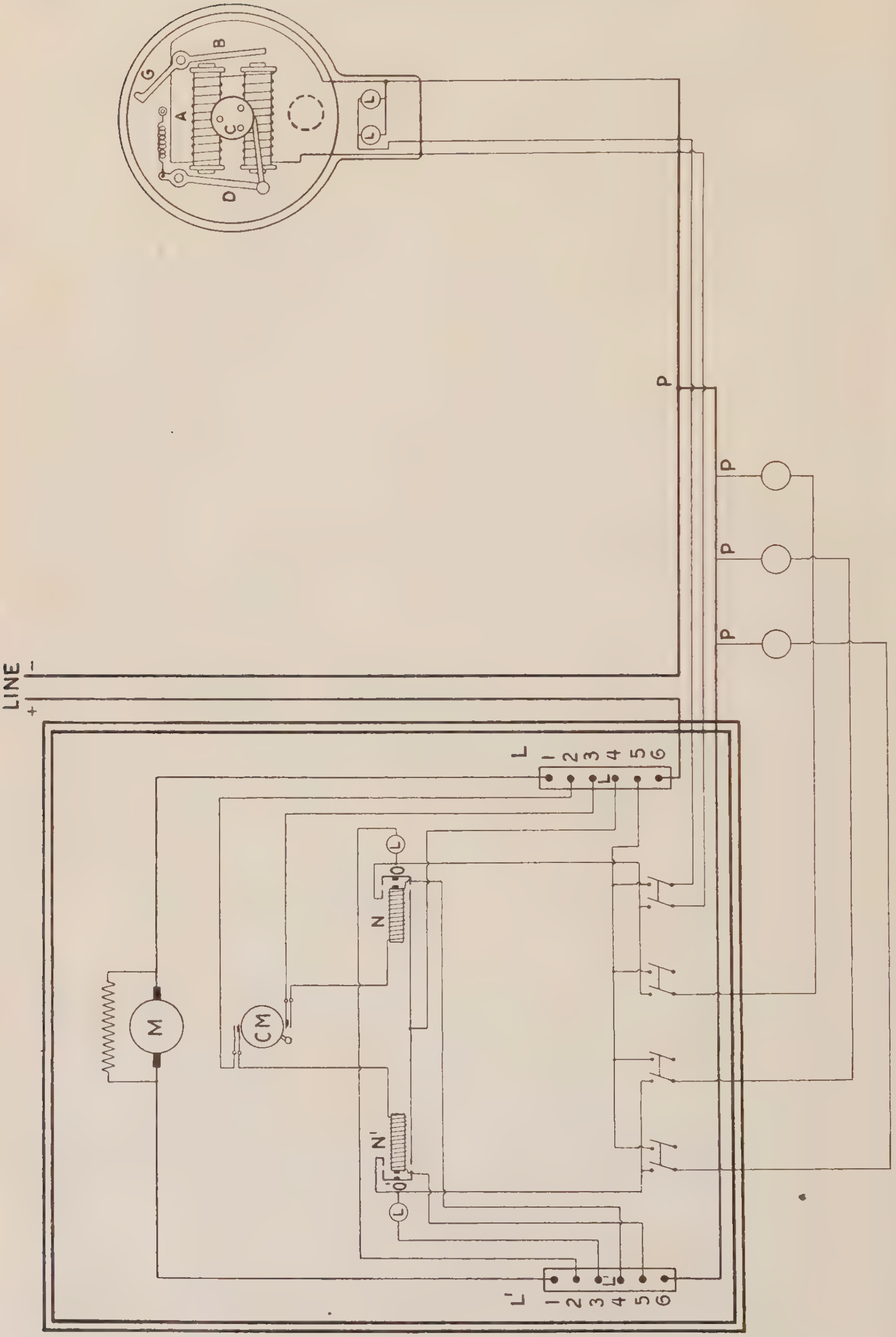

G
B
A
C
D
L
L
P
P
P
P
LINE
+
–
L
1
2
3
4
5
6
M
CM
N
N'
O
O
L
L
L'
1
2
3
4
5
6

FIG. 232.—Wiring of Fire Timing Device. Chas. Cory & Son.

When the lower contact under the circuit maker is made current flows from L3 through electromagnet N to L′4. When N is energized it attracts its armature O, which completes a circuit from L4 to the left-hand blades of the two right-hand switches. These furnish current to all the electromagnets in the indicators on one side of the ship, the return being through a common wire, as indicated at P, P, P. The right-hand blades of the switches are fed from L5 and lead to the lamps in the indicator and through the common return. When armature O is attracted, a branch circuit feeds the lamp L, leading to terminal L′2. This lamp is covered with a green shade, which is illuminated, and furnishes an indication that circuit for all the starboard indicators is complete.

When the upper contact over the circuit maker is made by CM, current flows from L2 through the electromagnet N′ to L′5. N′ is energized and attracts its armature O′, which completes a circuit from L4 to the left-hand blades of the two left-hand switches. These furnish current to all the electromagnets in the indicators on the other (port) side of the ship.

When armature O′ is attracted, a branch circuit feeds the lamp L, leading to terminal L′3. This lamp is covered with a red shade, which is illuminated, and furnishes indication that circuit for all the port indicators is complete.

N and N′ are alternately energized, once in each revolution of CM, so all the starboard and port indicators are energized once for each revolution of CM, and at each time a new number shows on each disc.

The motor M revolves at a constant speed, and drives one of the discs at a constant speed. The second disc, which is driven from the first by a friction roller, drives CM, and may have its speed altered by changing the position of the friction roller, as moving it further towards the circumference of the first disc will cause the second to revolve faster. Thus the rapidity of the make of the operating circuits can be changed and the firing interval varied accordingly. A dial on the face of the transmitter is fitted with a scale graduated in seconds and minutes of time, and a lever, which operates the friction roller, moves a pointer over the scale. If a firing interval of two minutes is desired, it is only necessary to move the lever until the pointer is brought to the two-minute mark on the scale.

Whistle Operators.

These are installed for the purpose of electrically controlling the main steam whistle. The main steam-whistle apparatus is electrically controlled by an at-will switch in conning-tower and on bridge.

Installed in the steam-pipe connection to the whistle is a specially constructed globe valve and an operating case, which contains two multiple-wound electromagnets. This valve is entirely independent of the one used for hand control and is normally held closed by steam pressure and recloses by this pressure when forced open. The electromagnets are provided with a heavy armature, which operates against a strong spring. When the magnets are energized the armature is attracted and its motion is conveyed through a rod to the valve, forcing this open and admitting steam to the whistle. When de-energized the armature is drawn back under the action of its spring and the valve closes automatically by the unbalanced steam pressure.

The wiring connections of a system that has been extensively installed is shown in Fig. 233. This particular type shows two places of control, one at the point marked "key," which is located on the inside of the hinged case, the other at the "automatic" or "at-will" switch, which can be installed in some convenient place, or another may be wired in parallel with it.

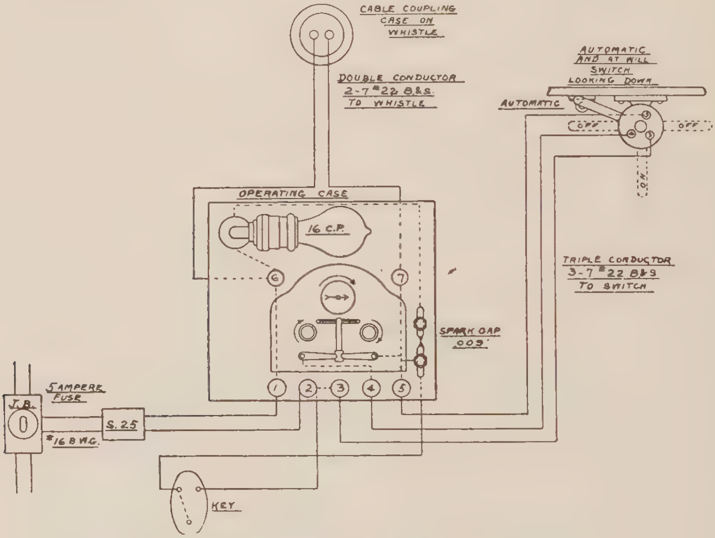

CABLE COUPLING CASE ON WHISTLE
DOUBLE CONDUCTOR 2-7 #22 B&S. TO WHISTLE
AUTOMATIC AND AT WILL SWITCH LOOKING DOWN
AUTOMATIC
OFF
OFF
ON
OPERATING CASE
16 C.P.
6
7
TRIPLE CONDUCTOR 3-7 #22 B&S TO SWITCH
SPARK GAP .005
5 AMPERE FUSE
J.B.
0
S. 25
#16 B.W.G.
1
2
3
4
5
KEY

FIG. 233.—Connections of the Whistle Operator.

The object of the clock mechanism is to provide closing of the operating circuit at certain predetermined intervals of time and to keep it closed for a certain interval and then open it. As the principal use of the automatic feature is for use in fog, the contacts are arranged to close at intervals of 54 seconds and to remain closed for 6 seconds, the whistle giving a blast during this interval. There are three positions for the hand lever of the automatic and at-will switch; "off," "on" and "automatic." The "automatic and at-will" switch is placed on the bridge and may be closed to "automatic" for fog signals, or to "at-will" for navigation or fog signals instead of using the hand pulls. The "key" is placed on the signal bridge and is generally used for sound signaling.

Method of Operation.—The circuit is wired on the full potential voltage of the ship's mains. The figure shows the operating circuit taken from a junction box through a 25-ampere switch and is connected to the terminals marked 1 and 2. If the automatic switch is "off" and the key is closed, current flows from terminal 2, through the key to the lower terminal of the spark gap, to and through the electromagnet in the steam pipe, returning to the line by terminal 1.

If the key is opened, and the automatic switch is closed to "on," current flows to terminals 2 and 3, through the automatic switch to terminal 5 and the path described above.

If the key is open and the automatic switch is closed to "at will," current flows to terminals 2 and 3 through the automatic switch to terminal 4, through the clock contact maker and then through the path above described. In each case the whistle is sounded each time the circuit is closed and gives a blast during the time it remains closed.

When the circuit is broken, the extra induced current caused by the collapsing of the magnetic field on the windings of the electromagnet discharges through the resistance of the lamp and the spark gap shown. This protects the contact points of the clock contact maker.

CHAPTER XV.

INTERIOR COMMUNICATION—TELEPHONE SYSTEMS.

STANDARD TELEPHONES.

At the present time, telephone apparatus of all kinds, for installation on our ships of war, is built according to standard specifications which have been the result of years of experience. Many types not described will be found on our earlier ships, but in ships recently built and those now building one standard will be used.

The Navy type telephones described herein embody the electrical and acoustic construction found best by years of experience in building telephone apparatus, and the mechanical construction necessary to produce a watertight telephone which will successfully withstand the hard service which they receive aboard ship. Since the same types of receivers and transmitters are used on all types of Navy telephones, the following brief description with special reference to the cause and effect of the most common troubles is given:

Receivers.—A sectional view of a receiver is shown in Fig. 234. It consists of a permanent magnet, on the poles of which are attached the small electromagnets. In front of the faces of these magnets, but separated from them, is an iron diaphragm. It will be observed that the diaphragm is clamped against a rubber gasket in the cap by a threaded binding ring. The cores, permanent magnets, electromagnets and terminal block are secured to a brass shell which is threaded to screw into the cap until the shell comes against the binding ring. In this position the faces of the electromagnet should be .010″ from the diaphragm. Most of the trouble which occurs in a receiver is due to this distance being varied. When receivers are taken apart, care should be used to see that the shell is screwed fully into the cap, for if it is not, the distance between the pole faces and the diaphragm will be greater, which will result in weak talking. On the other hand, should the diaphragm become bent or not clamped into the cap sufficiently tight to hold it firmly, it will come in contact with the pole faces and the receiver will not operate. A bent diaphragm, even though it does not come in contact with the pole faces, will not vibrate properly and should not be used. If an excessive current be allowed to flow through the coils, the electromagnets will become strong enough to attract the diaphragm in contact with the poles, and thus render it inoperative. Care should be taken to see that no rust or small particles of iron adhere to the pole faces and that nothing else occurs to interfere with the free vibration of the diaphragm.

Since the receiver is a polarized instrument it is imperative that the current flowing through it be in a direction which will strengthen the permanent magnets rather than oppose them. The terminals will be found marked + and −, and the cords provided with a color code, so that this point may be easily taken care of. It should be noted that the shell may be screwed into the cap and the wires attached to the binding posts, and the receiver tested before fastening on the back case. The case is secured to the cap by five screws, a sheet gasket being used to secure watertightness. The cap, shell and case are each formed from one piece of tough sheet brass, and have the greatest possible strength for their weight. Tests for opens, short circuits and grounds may be made in any of the well-known manners such as with the testing magneto, or voltmeter and battery.

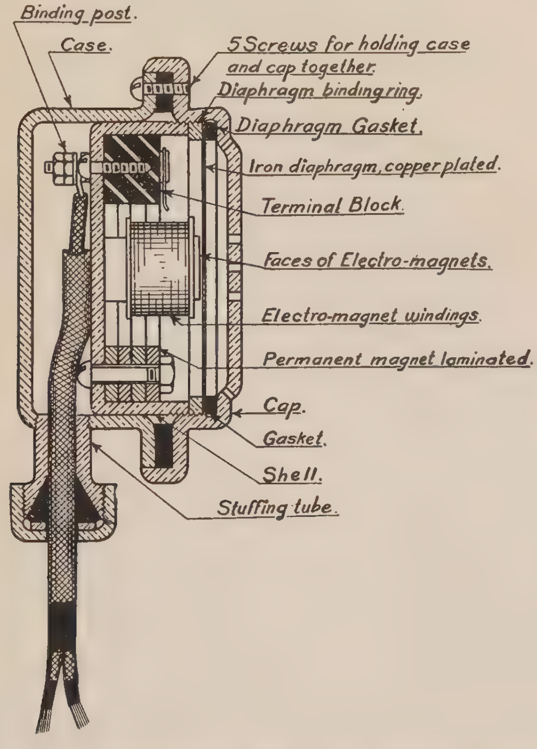

Binding post.
Case.
5 Screws for holding case and cap together.
Diaphragm binding ring.
Diaphragm Gasket.
Iron diaphragm, copper plated.
Terminal Block.
Faces of Electro-magnets.
Electro-magnet windings.
Permanent magnet laminated.
Cap.
Gasket.
Shell.
Stuffing tube.

FIG. 234.—Cross-Section of Navy Type Watertight Receiver.

The Navy Type Transmitter.—Ordinary telephone transmitters have the disadvantage that if they are held flat, that is, with the carbon electrodes horizontal, the granular carbon all rests on the back electrode, and the transmitter becomes inoperative owing to lack of contact between the front electrode and the carbon granules. Owing to the nature of the service which fire-control telephones undergo, it is extremely important that the transmitter should operate in all positions. In order that the granules should at all times be in contact with both electrodes, the electrodes of the Navy type Holtzer-Cabot transmitter are of conical form; that is, the front electrode is a cone and the back electrode is a hollow cone. Both electrodes are coated with thin sheet platinum which will not become tarnished or oxidized.

A diagram of this transmitter is shown in Fig. 235. The diaphragm, shown at 1, does not differ materially from that of the ordinary transmitter.

The back electrode 2 and the mica diaphragm 3 which supports the front electrode 4 form the container for the carbon, the rim of the cup in which the back electrode is mounted being crimped over the diaphragm so as to form a tight joint. The exterior of the back electrode cup is threaded and the cup is locked to the bridge 5 by a nut. The metal diaphragm 1 is carried by a stud extending through the mica diaphragm from the front electrode cone 4. Its adjustment is secured by varying the pressure with which it is set up against a rim on the bridge 5. To avoid grounding, both metal diaphragm and the cup containing the electrodes are insulated from the bridge.

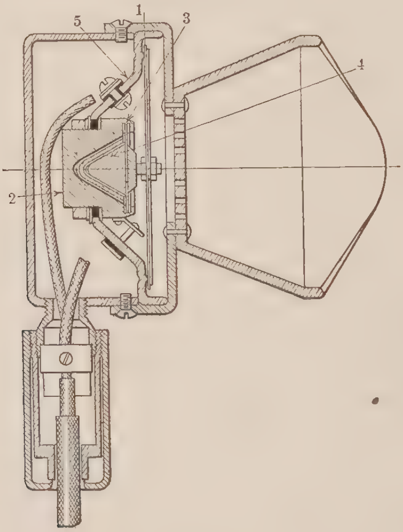


FIG. 235.—Navy Type Transmitter.

The terminals of the transmitter are carried by the bridge and are insulated from it.

But one point of adjustment exists in the transmitter and that is at the point where the diaphragm is clamped to the front electrode stud. The outer edge of the diaphragm rests on a knife-edge support, while the electrode stud passes through its center and is secured by two nuts, one on each side of the diaphragm. The best talking results are obtained when the diaphragm is "dished" or the center held in towards the electrode about .010 of an inch. If dished too much, talking will be clear but faint, if not dished enough, talking will be loud but rather harsh and broken and not very distinct.

TELEPHONE SYSTEMS.

A two-wire system of connections is used throughout the telephone installation. There are two distinct systems as follows:

(a) **Ship's Service Telephone System.**

(b) **Fire-Control Telephone System.**

Current for all talking circuits is provided either by motor generator, or storage battery, line voltage 12 to 20 volts. The calling apparatus (used only in ship's service telephone system) consists of a dynamotor supplying alternating current at 16⅔ cycles and 80 volts and a hand-ringing magneto as a standby. The same leads used for talking carry the ringing current.

Ship's Service Telephone System.

This system for larger vessels, consists of a central telephone switchboard, and telephones, types HB, HBc, D and DB, located in various compartments throughout the vessel for general communication. All the sources of power for the circuits are in the central station. For destroyers this system is not provided with a central telephone switchboard nor with alternating current ringing arrangements. A separate direct-current calling circuit is installed in common with other calls in the vessel.

Types of Telephones.—Telephones of types HB, HBc, D and DB are used on Ship's Service Circuits.

Type HB telephone is shown in Fig. 236 and consists of a watertight hand microphone set attached by a flexible cord to a watertight alternating-current bell, provision being made in the side of the bell box for holding the microphone when not in use. The operation of removing and replacing the microphone respectively closes and opens the talking circuit to the central switchboard.

It is of watertight construction especially constructed of extra heavy material to withstand rough use.

Type HBc consists of standard commercial material, but in other respects conforms to the same construction as above.

Type D is of commercial construction consisting of a switch pedestal carrying receiver and transmitter. The pedestal is mounted on an adjustable swinging arm.

Type DB is in all respects the same as type D except it is provided with a commercial alternating-current bell or buzzer as required.

A hand microphone possesses the following desirable features:

1. It can be used equally well by persons of any height.

2. It does not pick up the noises due to the operation of the ship nearly so readily as does the telephone in which the transmitter is in metallic connection with the bulkhead.

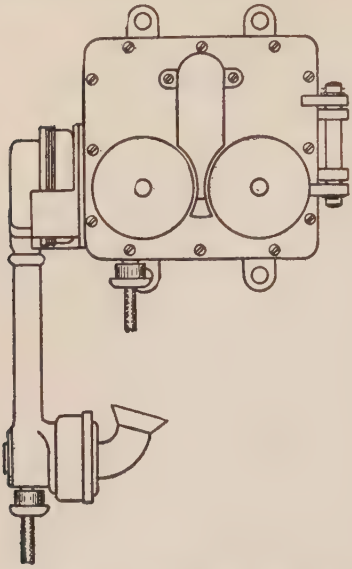


FIG. 236.—Telephone, Type HB, Type HBc.

3. When the receiver is placed to the ear the mouthpiece comes directly in front of the mouth, and it is therefore impossible to talk too far away from the transmitter.

4. The rolling of the ship is not so liable to cause a person injury in the case of a hand microphone as in the case of a telephone fastened solidly to the bulkhead.

The Navy standard hand microphone is designed to be strong, compact and efficient. There is a space in the handle for a connection block, which enables the cord to be renewed without requiring the opening of the transmitter or receiver cases. The transmitter is so mounted with respect to the handle that the faces of the electrodes are vertical in all ordinary positions in which the telephone is used. The handle is large and flattened, which enables the user to hold it with the least amount of fatigue. When the hand microphone is on its holder there is abundant room in which to grasp the handle without any danger of bruising the fingers or knuckles. The hand microphone can be put on or taken off its holder with one hand, there being no latches or levers to operate. This act also signals the switchboard for a connection or disconnection.

For signaling, a watertight alternating-current polarized bell is used. This is standard commercial practice and has the advantages: (1) It can be bridged across the two wires of the telephone line. (2) It has no spring adjustments. (3) It has no contacts. The bell is mounted entirely separate from the telephone.

Where the telephone is located in exposed positions, it is placed inside a composition metal box similar to a stowage box. This box is purposely left quite long so as to give a sufficient length of cord on the hand microphone without danger of its hanging outside the case and being damaged by closing the door.

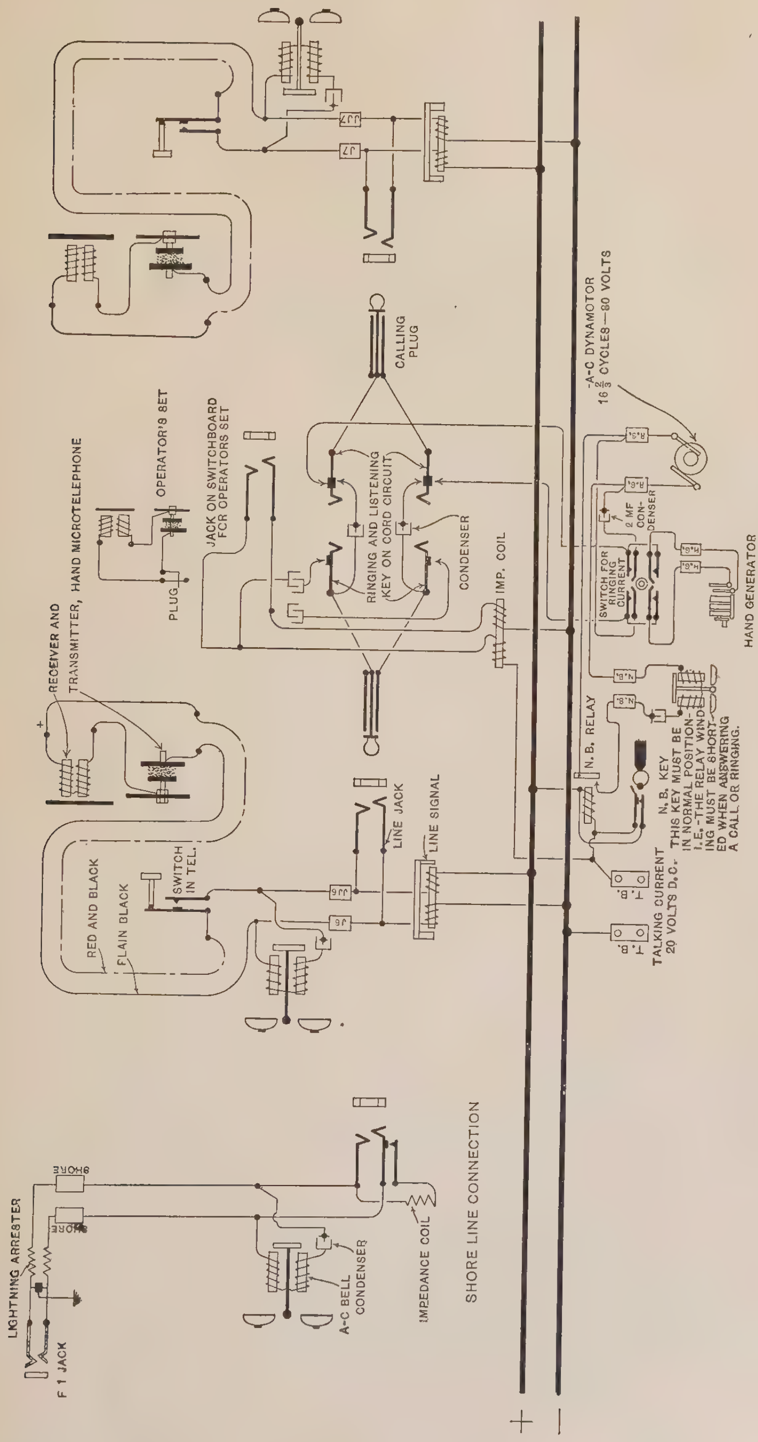

RECEIVER AND
TRANSMITTER, HAND MICROTELEPHONE
OPERATOR'S SET
PLUG
JACK ON SWITCHBOARD
FOR OPERATORS SET
CALLING
PLUG
RINGING AND LISTENING
KEY ON CORD CIRCUIT
CONDENSER
IMP. COIL
A-C DYNAMOTOR
16 2/3 CYCLES—80 VOLTS
R.S.
R.G.
2 MF
CON-
DENSER
SWITCH FOR
RINGING
CURRENT
H.G.
H.G.
HAND GENERATOR
N.B.
N.B.
N.B. RELAY
N.B. KEY
THIS KEY MUST BE
IN NORMAL POSITION-
I.E.-THE RELAY WIND-
ING MUST BE SHORT-
ED WHEN ANSWERING
A CALL OR RINGING.
T.B.
T.B.
TALKING CURRENT
20 VOLTS D.C.
J.J.7
J7
LINE JACK
LINE SIGNAL
J.J.6
J6
SWITCH
IN TEL.
RED AND BLACK
PLAIN BLACK
+
LIGHTNING ARRESTER
F 1 JACK
SHORE
SHORE
A-C BELL
CONDENSER
IMPEDANCE COIL
SHORE LINE CONNECTION
+
−

FIG. 237.—Diagram of Connections. Switchboard and Telephones for Ship's Service.

Switchboard (Fig. 237).—The standard switchboard now in use for ship's service is known as the **type C** switchboard. It is of the cord and plug type. The line to each telephone is connected to the telephone talking busses (16 to 20 volts circuit) with an electromagnet, operating the switchboard signal, in series. There are also connections to the line jack in the switchboard and to the bell circuit, in parallel. A condenser is in series with the bell. The **cord circuit** consists of an answering plug and a calling plug to fit the jacks; a ringing and listening key; connections to a jack for the operators' telephone sets; to a hand-ringing generator; and to the power-ringing dynamotors. The board is also fitted with a night bell and a shore-line connection.

The action of the system throughout a call is as follows: A party removes his hand microphone from the holder (Fig. 236) which allows current from the positive side of the generator to flow through one-half of the signal winding, then through the switch contact in the telephone, then through the transmitter and receiver, then through the other half of the signal winding to the negative side of the generator. The current flowing through the signal windings energizes it and causes the target to appear in front of the opening. This attracts the attention of the operator who takes the bottom plug of any pair of cords and inserts it in the jack which is immediately under the operated signal. He then presses down the lever of the ringing and listening key of the cord circuit used which connects his head telephone in multiple with the calling telephone. After ascertaining the number desired he takes the top plug of the pair and inserts it into the jack of the line called for. He then presses the lever of the ringing and listening key up, which throws the 16-cycle, 80-volt generator across the line and rings the bell at the telephone. As long as both parties are talking their signals remain in sight. When either hangs up, the signal of his line disappears. The operator thus knows without listening in if the calls are answered and when a conversation is finished.

Direct current from the generator does not flow through the bell at the telephone, for the reason that a condenser is used in series with it. Briefly, a condenser will allow alternating or fluctuating currents to flow without offering much resistance, but presents an open circuit to direct currents. The condensers in the cord circuit readily allow the fluctuating currents caused by the transmitter on one line to flow through to the telephone on the other line.

It should be noted that the cord circuits are independent of each other so that if one cord pair is in trouble, another may be used. The chief objections to cords which have heretofore been urged have been that they require such a large amount of space and that, due to the rolling of the ship, they would become entangled. Both of these objections have been overcome in the present design; the former by putting the cords in the case in such a manner that the total space required is less than for a cordless type of board, and the latter, by arranging the weights for the cords so that they are held from lateral motion by rods running from the top of the case to the bottom.

RINGING CIRCUITS (Fig. 237).—The ringing dynamotor is supplied with current from the interior-communication switchboard, and the generator leads are taken to terminals on that switchboard. Two power dynamotors were installed formerly, but the latest practice is to use one power dynamotor and one hand-ringing generator. The connections of the hand-ringing generator and the night bell can be followed from the diagram.

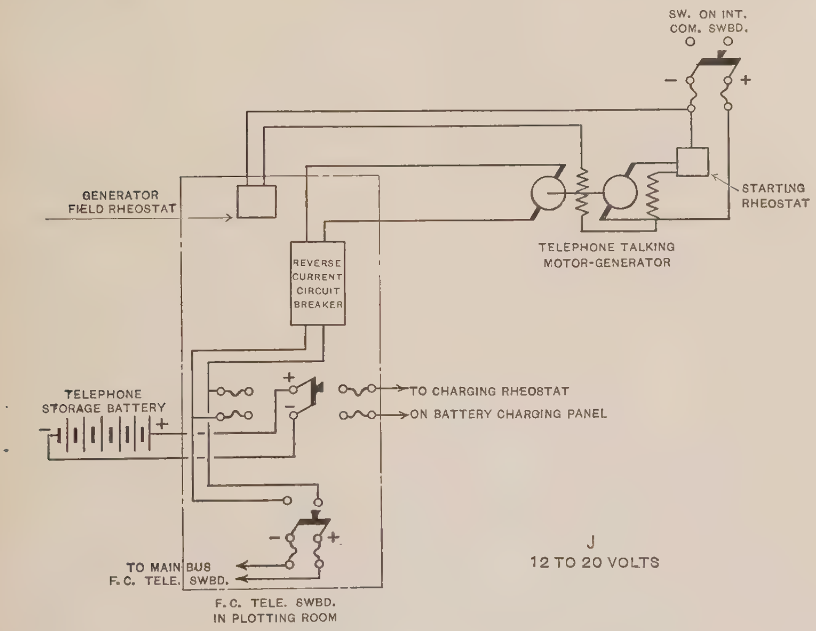

SW. ON INT. COM. SWBD.
−
+
STARTING RHEOSTAT
GENERATOR FIELD RHEOSTAT
TELEPHONE TALKING MOTOR-GENERATOR
REVERSE CURRENT CIRCUIT BREAKER
TELEPHONE STORAGE BATTERY
−
+
TO CHARGING RHEOSTAT
ON BATTERY CHARGING PANEL
J
12 TO 20 VOLTS
TO MAIN BUS F.C. TELE. SWBD.
F.C. TELE. SWBD. IN PLOTTING ROOM

FIG. 238.—Current Supply for Telephone Talking.

The *dynamotor* is of a commercial type, 25 watts, with generator end wound for 80-volt, 16⅔-cycle, alternating current, with motor end wound for 120 volts direct current. It is of the single-field, double-wound armature type, the field frame being circular in form and of laminated or solid steel.

MOTOR-GENERATOR CONNECTIONS (Fig. 238).—The motors of the two telephone talking motor generators receive their current from switches on the interior-communication switchboard (one of these motor generators is used as reserve and only one is shown in the diagram). The circuit from the generator leads through a reverse-current circuit breaker to a switch connecting to the bus bars in the fire-control switchboard. A storage battery is connected to float on the line. Connection is also shown for charging the storage battery. Connection is made from the fire-control busses to the telephone talking busses on the ship's service switchboard, as well as to the fire-control circuits and the maneuvering circuits.

The **motor generator** is of a commercial type with generator wound for a normal voltage of 20 direct current, and with motor wound for 120 volts direct current.

The generators used for the telephone systems on board ship are specially designed for noiseless operation. This is secured by so shaping the slots and pole pieces that there is no sudden change in flux density through which the conductors are passing, and by using a very large number of coils and commutator segments, which prevent any great difference in voltage from existing between adjacent segments.

A **choke coil**, which is a very low-resistance impedance coil, is usually placed in series with the generator, and tends to smooth out the current variations and make them less noticeable. It is found that a generator and choke coil will operate much more noiselessly under load than running free, and for that reason a small load coil is supplied. A **condenser** is also connected across the leads, which tends to still further absorb the fluctuations. The condenser and load coil also serve another important purpose, which is to prevent cross talk between the various circuits.

SHORE-LINE CONNECTION.—The shore-line connection is installed to provide for connecting any telephone on board the ship to any station on shore. The circuit which has been adopted for the cord type of switchboard is one that gives efficient shore service with very little complication on the shore line.

The shore exchange may be either magneto or common battery, and as the operation of the two types is quite different, each will be considered separately.

Considering briefly the operation of a common battery shore telephone, the line is normally open to direct current at the subscriber's station by reason of the switch contact on the telephone being open, and by reason of the condenser which is in series with the alternating-current bell.

When a subscriber removes his receiver from the hook the switch contacts are closed, which permits direct current from the central office to flow through his transmitter and receiver. There is in series with the line at the central office a relay which closes a contact and lights a lamp to attract the attention of the operator when the subscriber removes his receiver and closes the circuit as described above. When the operator, at the shore exchange, plugs in to answer this call, she cuts out the relay which lights the lamp, and cuts in a relay associated with her cord circuit, which is so arranged that so long as current is flowing its contact is open. When the subscriber has finished talking, however, and hangs up the receiver, the circuit through this relay is opened, which allows its armature to fall back and light the lamp associated with the cord used. This is the operator's signal to disconnect.

If the line from the shore exchange is connected to the ship's telephone switchboard instead of to a telephone, it is evident that in order to call the shore operator, it is only necessary to close the shore-line circuit. This is accomplished by putting an extra spring on the jack of the shore line, as shown in Fig. 237, and so arranging it that when the ship's operator plugs into this jack, an impedance coil of about 300 ohms' resistance is connected directly across the terminals of the line. This impedance coil does not permit of much leakage of the talking currents. It does, however, keep the signals of the shore line at the shore exchange in such a position as to indicate that the line is in use.

It is impractical to connect the ship's telephones directly across the terminals of the shore line when a shore connection is desired, and satisfactory operation would not result even were it possible to do this for the reason that the ship's telephones are designed for a different voltage than might be used on the shore exchange. It is preferable, therefore, to leave the ship's telephone connected directly to its own source of current on board the ship and make the connections between it and the shore line inductively, that is, so that no direct current from the telephone motor generator will flow on to the shore line, and vice versa.

It is readily seen that if the shore exchange and the ship's telephones are operated with the same voltage and that the lines were so connected together that the two sources of current were in electrical connection with each other, they might be so connected that they would oppose each other, and the result would be that there would be no current flowing to operate the telephones. If, on the other hand, they were connected in the reverse manner, the voltages of the two would be added, which would give twice the normal voltage and result in poor operation.

An inductive connection between two lines can be secured by means of a repeating coil or by means of a condenser. It is believed that the condenser arrangement is the more satisfactory. The calling plug and the answering plug on the standard ship's telephone circuit are not directly connected together, but are connected inductively by means of condensers. If, therefore, the calling plug of any pair of plugs is inserted into the shore line and the answering plug into the line of the ship's telephone, the two will be inductively connected.

The shore operator calls the ship's switchboard by plugging in on the line and ringing the bell by means of her alternating-current generator.

Considering, now, the case of the shore exchange of the magneto type, the operation of the subscriber's telephone on such an exchange is as follows: When the subscriber desires to signal the central office, he does so by turning the crank of a small generator in his telephone. Current from this generator operates a drop at the central station, which attracts the attention of the operator. No direct current is supplied to the line of a magneto system. A common battery telephone will not, therefore, operate when connected across the line, as there is no current to operate it. It is essential, therefore, that current from the ship's telephone motor generator be supplied to a ship's telephone when it is connected to a magneto shore line. It is also necessary that no direct current flow out over the magneto shore line, as it would affect the apparatus at the shore exchange in a detrimental manner.

The shore line, as shown in Fig. 237, will operate satisfactorily when connected to a magneto exchange. In order to signal the exchange, it is necessary to insert the calling plug of any pair of cords of the ship's switchboard into the line jack, and press the ringing key so as to throw the alternating current on to the line. The answering plug is inserted into the line of the telephone on board the ship which desires the shore connection. It is impossible to answer a call on the shore line by inserting the answering plug into it, for the reason that there is no current on this line, as explained above, and, therefore, nothing to operate the transmitter of the switchboard operator's set. As stated above, it is necessary to insert the calling plug into the shore line and the answering plug into the jack of some line on board the ship.

DIRECTIONS FOR OPERATING TYPE C SWITCHBOARD.—When a party takes down his telephone at any station, a signal appears at the switchboard under the name of the calling station. The operator then proceeds as follows:

1. Throw the night-bell key to the normal position. This is very important, as throwing the key to this position short circuits the winding of the night-bell relay. Unless this is done, cross talk and cross ringing may result.

2. Take *answering* plug of *any* pair of cords and insert it into the jack of the calling line.

3. Throw the ringing and listening key of the cord pair used to the listening position. This puts the operator's telephone in connection with the calling party.

4. Take the *calling* plug of the pair of cords used and insert it into the jack of the line called for.

5. Throw the ringing and listening key of the same pair of cords to the ringing position. This rings the bell of the called-for station.

6. When the called-for party answers, his line signal will appear, and remain in sight as long as the conversation continues. When either party hangs up his phone, the signal of his line disappears and the operator is thus

advised when the conversation is finished. He should then remove the plugs from the jacks and allow them to return to the normal positions in the sockets.

7. In case the calling party asks for the shore line, insert the *calling* plug into the jack of the shore line. In case the shore exchange is common battery, no other operation is necessary, as the proper signal will be exhibited on the shore-exchange board. In case the shore exchange is magneto, press the ringing key. When the calling party's signal disappears, remove plugs.

8. To answer a call from the shore exchange: When the shore-line bell rings insert the *calling* plug of any cord pair into shore-line jack and *answering* plug into the jack of any line. Pressing the listening key puts current on the operator's set from the local source. After finding out the desired station, ring that station with the calling plug of *any* pair and then remove calling plug and transfer *answering* plug of the *first* pair used to the jack of the called-for line.

If care is taken to connect in the shore exchange so that the positive line runs to tip spring of shore-line jack, the call can be answered by inserting answering plug into shore-line jack. In this case battery current from the shore exchange is flowing through the operator's telephone. If the shore exchange is magneto, there is no current on the line and the call must be answered as first detailed.

Instructions Regarding Connecting Up and Maintaining Telephone System.—It is advisable when working on the terminal strips in the back of the board with the signal frame let down to cover the backs of the signals with heavy paper to prevent dirt, small wires, etc., from getting into the jacks and signals.

Any line signal can be removed from the front of the board without disturbing any adjacent signal and without putting the board out of operation. This can be accomplished by the use of a screw-driver alone without the necessity of any soldering.

The two-line connections to the jack are left long enough to pull out in front of the board. They can be removed from the jack by loosening the screws which hold the terminals which are on the ends of the wires. It should be remembered in putting these wires back that the *plain green* goes to the sleeve, *i. e.,* the long spring, and the *green and yellow* to the tip spring.

The ringing and listening keys may be taken out for inspection by loosening the screws in the escutcheon plate and pulling the keys and wires up through the opening.

The talking motor generator must have load coil and condenser connected, as otherwise the circuits will not be noisy, but may cross talk and cross ring.

A 2 M. F. condenser is connected in series with the ringing generator. This prevents direct current from the talking generator from flowing through the ringing generator. It also limits the ringing current to the required amount and protects the generator in case of a short circuit on the ringing leads, or in case it is attempted to ring on a shorted line. If this condenser is left out there is apt to be a disturbance on one telephone when another is being rung.

Fire-Control System.

These circuits consist of telephone types CC and CN installed in groups in circuits controlled by switches on a fire-control telephone switch panel, and provides communication between officers, guns, etc., required during action. A detailed description of the fire-control circuits is given in another chapter.

CHAPTER XVI.

INTERIOR COMMUNICATION—FIRE-CONTROL SYSTEMS

The fire-control system has for its object the efficient and accurate control of a ship's battery in action. To produce such control it is necessary to have some system of exact and prompt communication between the fire-control stations and the guns.

This is done by visual signals, telephones and voice tubes. The visual signal system transmits certain standard orders, ranges, and deflections. The telephone system affords direct communication between certain stations. The voice-tube system parallels the telephone system.

The visual system and telephone system are used in conjunction with each other. The voice-tube system is used for the same purpose as the telephone system as a check, and to replace it in case of necessity. There being no electrical features in the voice-tube system except call bells, it will not be considered in this chapter.

Fire-Control Telephone System.

The object of this system is to afford direct communication from the different fire-control stations to the class of guns controlled from each station, with inter-communication between certain of these stations. In general, there are two stations for the control of the turret guns, one on each mast in a specially constructed top. Other control stations are those for torpedo defense, both forward and aft on the starboard side and the same on the port side.

Telephones.—The telephones used for fire-control circuits are designated as types CC and CN.

(a) Type CC consists of a telephone head set with two microphone receivers, Navy standard type, connected in series and suspended on a webbing head gear, and held against the ear by a spring suspended at back of neck. The plug is so designed as to have a ½ M. F. condenser installed as a part of the receiver circuit.

(b) Type CN consists of receivers similar to receivers of the type CC telephone in conjunction with a transmitter having conical electrodes and also incorporating as an integral part of the set a ½ M. F. condenser and a cut-out push button, which must be closed for talking.

For diagram of connection of these types see Fig. 239.

From the bus bars the circuit is brought through the impedance coils to the circuit switch. Voltage of the bus bars is maintained between 12 and 20 volts.

Impedance Coils.—The impedance coil is a coil with large self-induction and small ohmic resistance, whose function is to effect the supply of direct current to the telephone while it confines the variations of current caused by talking, which are alternating in character, to its own circuit. Thus, in preventing the leakage of these alternating impulses to the other circuits, the impedance coil performs its function of preventing cross talk. To a steady direct current it offers only its ohmic resistance, but to alternating or fluctuating current a high resistance due to its self-inductance. All telephones in any circuit are in parallel; therefore, the greater the number of telephones in a circuit the more current is needed to give each telephone its proper share. For this reason, 3-ohm coils are used where a large number of telephones are employed and 10-ohm coils where a small number are employed.

Experience has shown that 10-ohm coils give good talking results with two to ten telephones and that 3-ohm coils give best results with from six to twenty telephones.

Condensers.—A condenser is an electrical appliance so constituted that electromotive force applied to it stores up energy in the form of electrostatic stress, which stress starts this energy back in the form of current when the constraining electromotive force is removed.

In the case of fire-control telephones, where the inductance (impedance) and capacity (condensers) are in series, the talking efficiency is improved. In such a case the only current which goes through the receivers is alternating in character, and is generated when the diaphragm of the transmitter receives the impulse from talking, and hence is necessarily very small. Under normal conditions, therefore, no heating or other deleterious effects due to the flow of current will be obtained in receivers when these small condensers are used.

Source of Energy.—On vessels up to and including the *Arkansas* and *Wyoming,* the fire-control telephone switch panel may be energized by either of two telephone motor generators. Later ships are supplied with one motor generator and a storage battery. The storage battery, like the motor generator, is arranged to supply the ship's service telephone system as well as the fire-control system. The battery is of sufficient capacity to supply current for telephones for a period of 30 days' continuous use.

The storage battery, consisting of an appropriate number of cells, is so designed as to "float in" on the line. The battery should first be charged

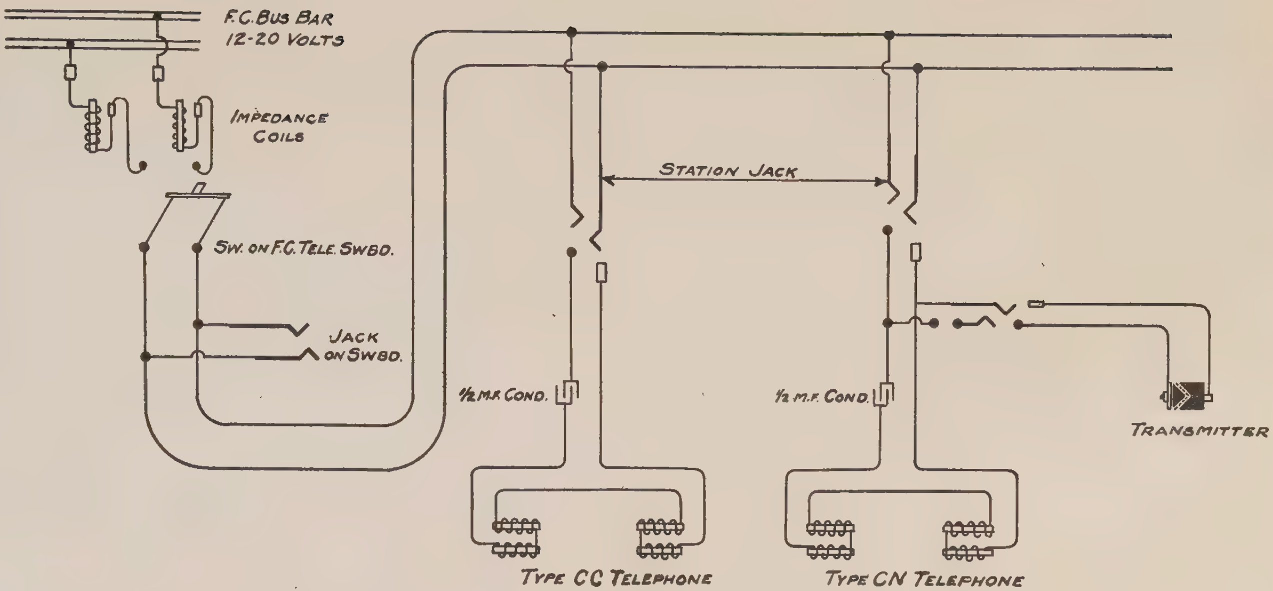

F.C. BUS BAR
12-20 VOLTS
IMPEDANCE COILS
SW. ON F.C. TELE. SWBD.
JACK ON SWBD.
STATION JACK
½ M.F. COND.
½ M.F. COND.
TRANSMITTER
TYPE CC TELEPHONE
TYPE CN TELEPHONE

FIG. 239.—Diagram of Connections, Fire-Control Telephones CC and CN.

from the ship's circuit to its normal potential by closing switch C down (see Fig. 240), and then thrown in across the motor generator lines with the telephone outlets, switch C up, A and B closed. The motor generator leads are fitted with a reverse-current circuit breaker C. B. If for any reason the motor generator is suddenly stopped or should the voltage fall below normal, the battery, being across the line, will automatically take charge and supply the telephones, while the reverse-current circuit breaker will instantly open and thus prevent a short circuit of battery through the armature of the motor generator.

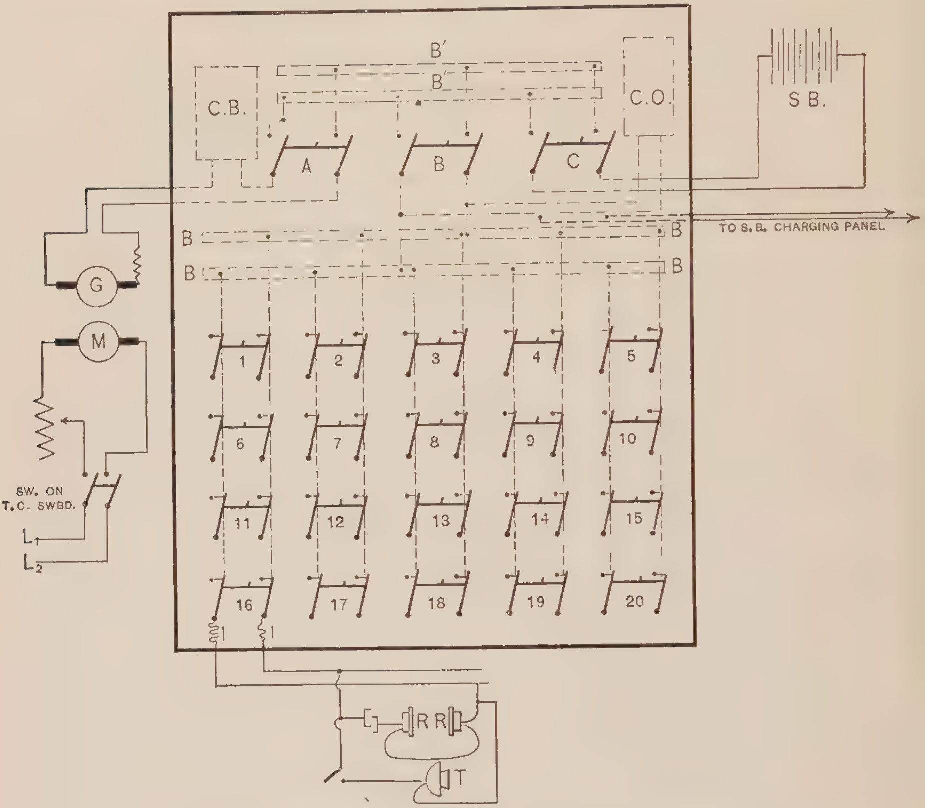


FIG. 240.—Fire-Control Telephone-Circuit Switchboard.

The different circuits are taken off the main bus bars as shown in Fig. 240, which represents a fire-control telephone system of 20 circuits. Each is provided with an impedance coil shown at I, in the circuit leading from the board. The circuit shown indicates how one set of phones, consisting of receiver RR and transmitter T is connected in parallel to its individual circuit.

Telephone Circuits.—The general arrangement of the various circuits is illustrated in Fig. 241. This shows two sub-stations, SS No. 1 and SS No. 2, which, in this case, are in one compartment. In this compartment is a transfer-switch panel containing the switches 1 and 2. This circuit shows the means of communicating from the turret control stations to the turret stations. 10 is the forward control station and 14 is the after station; the

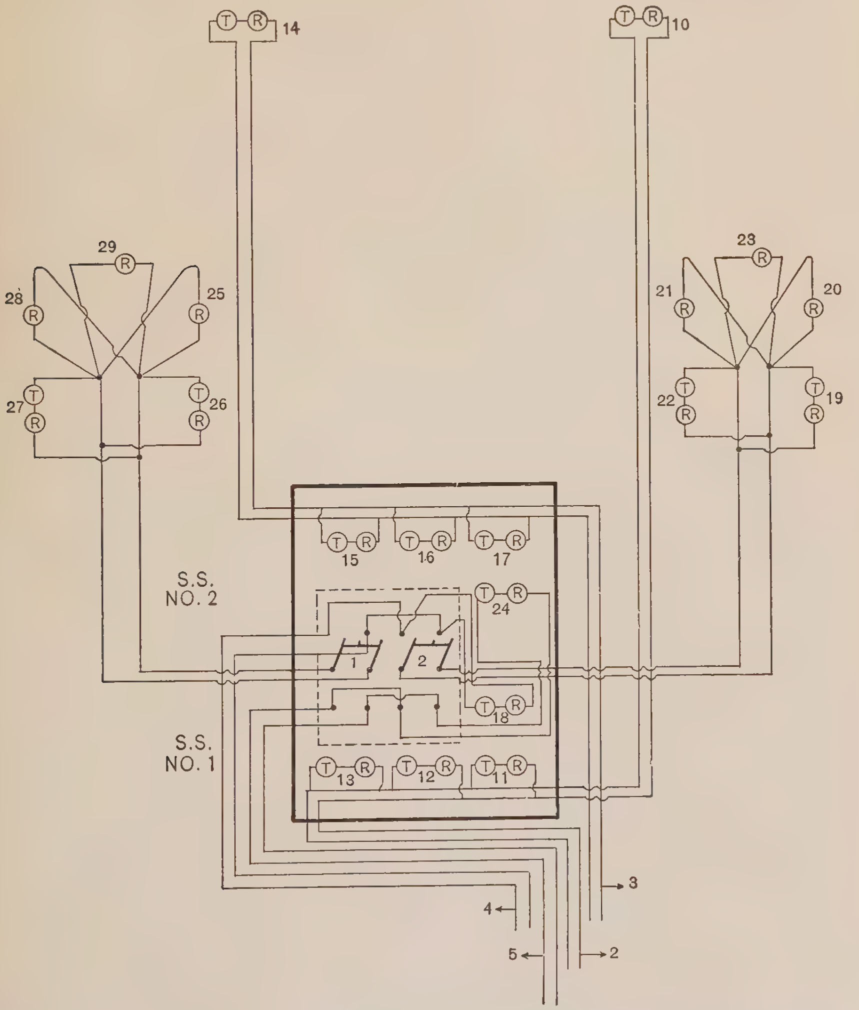

T
R
14
10
29
28
25
23
21
20
27
26
22
19
15
16
17
S.S.
NO. 2
24
1
2
18
S.S.
NO. 1
13
12
11
3
4
5
2

FIG. 241.—Telephone Circuits to Turrets.

group of telephones 19, 20, 21, 22 and 23 are in the forward turret and 25, 26, 27, 28 and 29 are in the after turret. The circuits 2, 3, 4 and 5 at the bottom lead to the corresponding numbered switches on the fire-control switchboard.

When No. 2 circuit switch is closed on the switchboard, it will be seen that No. 10 is in communication with 11, 12 and 13. There is an operator at each one of these telephones with the head receivers in place. The range, deflection and any battle orders are communicated over the same line, and operator at 11 takes and keeps the range, 12 the deflection and 13 the general orders. These orders are communicated to the operator at 18 who makes the connections and passes the word given to him. If No. 10 gives instructions to the forward turret, the operator closes switch 2 up, which puts his phone in connection with all the phones in the forward turret. When he passes the word the sight setters at 19, 20 and 21 get it and set the sights accordingly.

If the after turret guns are to be controlled from the forward station, switch 1 is closed up. The operator at 18 can pass the word to both turrets at the same time or to either one, depending on how the switches 1 and 2 are closed.

If the forward turret is to be controlled from the after station, 15, 16 and 17 get the word, and it is passed by an operator at 24 who closes switch 2 down, when he is in communication on current from circuit 5. To communicate with the after turret from the after control station, switch 1 is closed down.

Either control station can thus communicate with either turret or both at the same time.

Stowage Boxes.—All telephones, except those in the sub-stations, when not in use are kept stowed in watertight boxes secured permanently at places conveniently near where they are to be used. The transmitters and receivers are connected to terminals in these boxes by flexible conductors so they may be adjusted in place on the head and the operator be free to move around. For the phones for divisional officers, receptacles are installed at suitable places, where the phones may be plugged in.

FIRE-CONTROL TELEGRAPHS AND INDICATORS.

The fire-control telegraph and indicator system has for its purpose the transmission of certain standard orders, ranges and deflections, and other important information necessary to the accurate control of the battery by visual means, and is used in conjunction with the telephone system. There follows a brief description of these various circuits, their purpose, etc., and a description of the electrical features involved where they have not been described elsewhere.

Range, Deflection and Battle Order (Motor Type).

This system is used for transmitting ranges, deflection and battle orders from the sub-station to the sight setters, pointers and trainers of the turret guns, also indicating the same at the other station named below.

The system consists of two transmitters, two check indicators and a transfer-switch panel in the sub-station; three indicators and three action cut-out switches in each turret; two indicators in the fire-control tower, one in the fore and one in the main top.

Current is supplied from 120-volt bus bars on the interior-communication switchboard.

The transmitter and indicators are built on the same electrical principle as the revolution indicator (motor type) described in Chapter XIV, with the difference that the system is fitted with four 5-pole and three 2-pole transmitting units, and is capable of transmitting ranges up to 19,950 yards at 50-yard intervals, and deflection from 0 to 99 degrees. The orders transmitted are "fire" or "cease" as required.

Turret Local Fire-Control System.

This system enables the turret officer to control the firing of the turret guns by means of visual indications, which inform the gun pointers and turret crew as to the next gun to be fired, readiness of guns to fire, etc.

A complete system is installed in each turret and consists of a control panel in turret officer's booth, and indicator panels at each pointer's station and at breech of each gun. The turret gun-firing circuit is run in conjunction with the turret local fire-control system, the switches on the control panel in turret officer's booth being used in connection with both systems.

The control panel contains three single-throw knife switches, the necessary delayed action coils, and indicator lamps. The knife switches are held in the open position normally by springs. The indicator lamps are each inclosed in a cylindrical shield to prevent illumination of the wrong indication. The delayed action coil is controlled by a single-pole double-throw flush switch in all 2-gun turrets. In 3-gun turrets the delayed action coils are controlled through the knife switches on the turret officer's control panel.

On all vessels prior to the *Arizona* the indicator lamps are supplied with current from either the light or power system. There is mounted on the control panel in turret officer's booth for this purpose a double-pole double-throw supply switch. The handle extends through one side of the panel and carries a pointer which indicates three positions: "Lighting," "off," "power." Vessels, commencing with the *Arizona,* will be supplied from the lighting mains only.

The cover of the control panel is hinged and has slots through which project the handles of the knife switches. A sliding latch with spring automatically locks the switch in the closed position when the switch is closed. Name plates above each switch indicate the function of the switch. Ground-glass windows are provided for the indicator lamps and are marked and colored to indicate each particular gun.

Single-indicator lamps are provided and are marked and colored to indicate the particular gun near the breech of which they are mounted. The indicators at the pointers' stations contain three lamps and indicate which guns are ready to fire.

The system is controlled through the control panel in turret officer's booth and by "ready" switches at the breech of each gun. Closing a "ready" switch of a gun lights all indicator lamps for that gun in the turret, signifying that the gun is loaded and ready to fire, provided the corresponding switch on the control panel is closed.

Torpedo-Firing System.

By means of this system any torpedo tube may be fired from its directing station in the conning-tower or from the torpedo rooms, but not from both at once. Two firing panels are installed in the conning-tower, one at the port and the other at the starboard station; there are also two in each torpedo room, one port and the other starboard. Current for this system comes direct from the interior-communication switchboard at 120 volts. It is a simple contact system with illuminated letter indicators indicating the tube fired.

Cease-Firing Circuits.

Cease-firing gongs are installed for the purpose of giving a general signal for "cease firing." It is usual to so wire them that they can be controlled from the fire-control tower, central station and conning-tower. The circuit is subdivided into two parts, one for main battery and the other for torpedo defense.

The main-battery gong is an 8″ vibrating gong, while the torpedo-defense battery is equipped with 10″ gongs. The gongs are mounted in sub-central, torpedo rooms and in the vicinity of all guns and torpedo-defense stations.

Power for this circuit is from a switch on the interior-communication board, and operates at ship's voltage.

Turret Salvo-Firing System.

This consists of a number of contact makers, bells and buzzers arranged as a signal for controlling the fire of the turret guns, from either of the tops, fire-control tower, sub-central station and one of the highest turrets.

Switches and contact makers in the fire-control tower and in the sub-central station are arranged to permit signals to be made separately to any one or more turrets locally or from the forward top, and to the forward group of turrets or to the after group locally, or to the after group from the after top. The forward turrets may be controlled independently of the after turrets. The bells are permanently installed and the buzzers are portable with portable cord and attachment plug.

The system is wired on 125 volts with separate circuits for the bells and buzzers.

Torpedo-Defense Salvo-Firing System.

This consists of a number of contact makers and buzzers, arranged as signals for controlling the fire of the torpedo-defense guns. For these guns there are contact makers at each torpedo-defense station, operating buzzers as a " fire " signal at each gun, the guns being arranged in groups or sectors.

The contact makers are all in circuit with master contact makers in the fire-control tower and sub-central station, so that the local circuit can only be energized when a master contact maker is closed.

Turret Tell-Tale System.

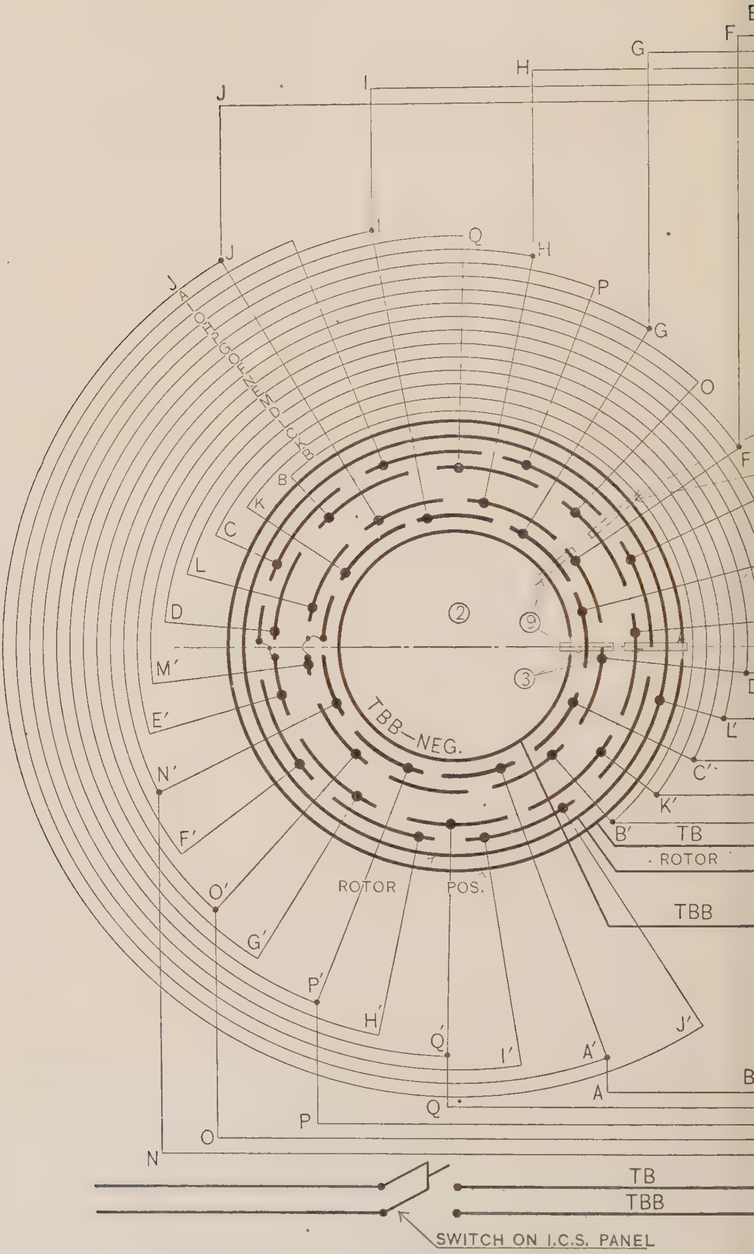
This system is designed to show, in any one turret, its relative position to any adjacent turret or turrets, and also the relative position of the turret with the center line of the ship. It may be applied to any number of turrets, but only those turrets which affect the movement of other turrets, by mechanically fouling of guns or by the danger of shooting away muzzles, need to have an inter-connected system. The system as a whole comprises both electrical and mechanical transmitters and indicators, the indicators, both electrical and mechanical, being combined in one instrument.

The mechanical transmitter is intended for local signals only, that is, to show the relative position of the turret in which it is located with the center line of the ship. It consists of a set of gears and shafting connected to a rack on the inside of the barbette.

The electrical transmitter is for the purpose of transmitting indications to adjacent turrets only.

The indicators are made with two, three or four dials to suit conditions; the pointer of one dial in each instrument is operated mechanically and locally, as described above, and the other pointers of the dials are operated electrically from other turrets. The pointers are of the shape of miniature turrets and guns so as to make the indication more realistic.

Wiring Plan.—The wiring plan of one transmitter and one indicator is shown in Fig. 242, 2 representing the transmitter in one turret and 1 the indicator in another. To have the indications of transmitter 2 shown in



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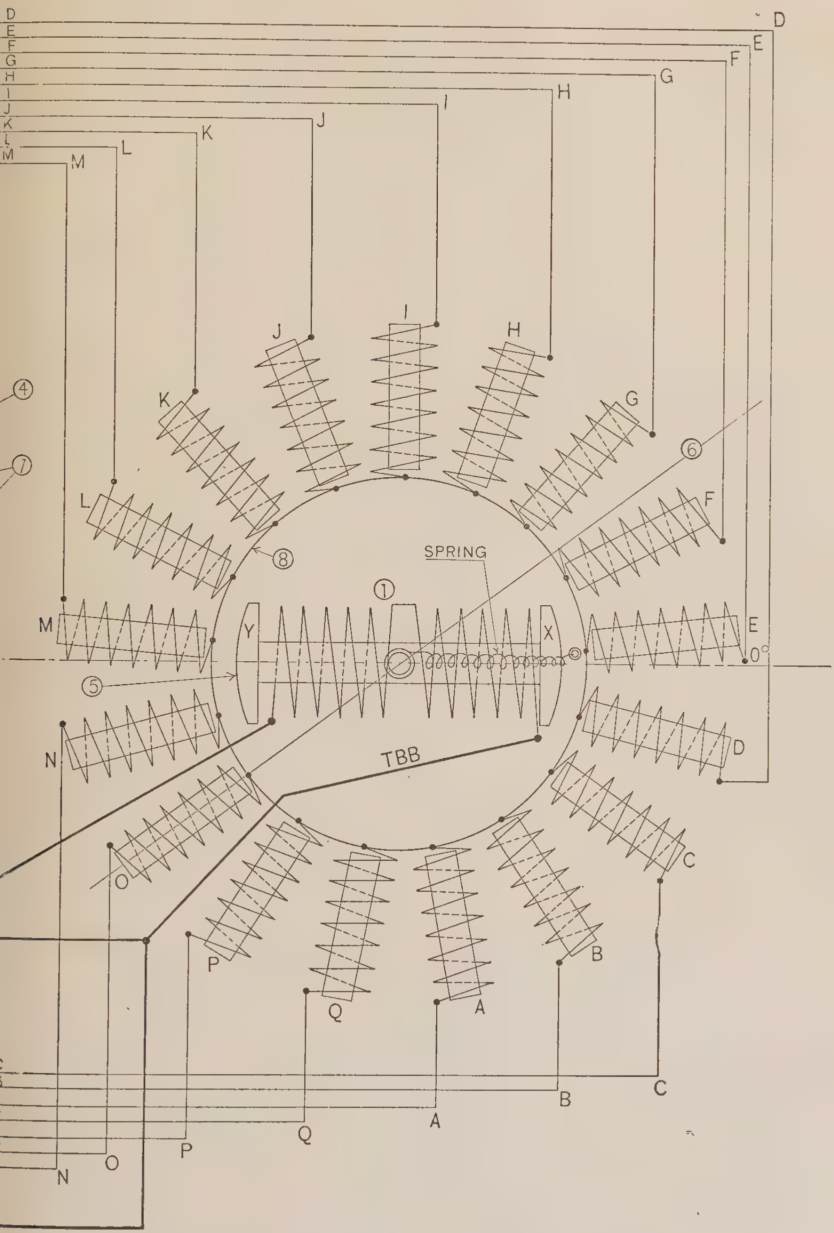
Q′
I′
A′
J′
B′
C′
K′
L′
②
⑨
③
TBB—NEG.
ROTOR
POS.
TB
ROTOR
TBB
A
B
Q
P
O
N
TB
TBB
SWITCH ON I.C.S. PANEL

FIG. 242.—Wiring Connections of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Q
④
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⑧
①
⑤
⑥
SPRING
X
Y
TBB
0°

ell-Tale System. Chas. Cory & Son.

more than one turret, other indicators would be connected in parallel with the one shown.

The **transmitter** consists of a watertight cylindrical case having a central shaft, which is geared to a rack on the inside of the barbette by a set of gearings and shafting. The central shaft carries an arm or contact maker, 3 or 9, which makes certain combinations of contacts with certain segments contained within the inner circumference of the cylinder band inside the case, whereby current is allowed to flow and energize certain magnets in the indicators. The contact maker always bears the same relation in degrees to the center line of the transmitter as does the turret to the center line of the ship; thus, if the turret revolves 10° from its zero or housing position, the contact maker revolves 10° around the contact segments.

The **indicator** consists of a watertight case containing a pivoted electromagnet as a center, shown at 1, around which are arranged 17 field magnets, A, B, C, D, etc. When the field magnets diametrically opposite each other become energized, while the pivoted magnet is also energized, it will assume a certain position. The pointer is attached to the movable magnet and moves with it. Two spiral springs are provided as conductors for the pivoted magnet, having terminals at their outer ends for the leading wires, and are so insulated and attached to the central spindle as to allow perfect freedom of movement of the pivoted magnet. As one spring is wound up, due to the motion of the spindle, the other is unwound, hence in no position of the magnet is the pull of the springs noticeable. The springs also serve to return the magnet and the pointer to the zero position when current is "off."

Method of Operation.—The system is supplied with current from a motor generator, over the wires TB and TBB. Suppose the turret has been turned through a certain angle from 0° and the contact maker, having turned through the same angle, has the position shown at 9. Then the pivoted magnet will take a position shown by the line 6, and the pointer will move through the same angle from its zero position. This is effected as follows: Current flows from the positive wire TB to the outer or positive segment of the transmitter, thence to section 7 of the contact maker 4, where it divides; part to the segment marked "rotor," then through its section wire to magnet 5, through magnet to the negative wire TBB, and part to segment O of the transmitter, through section wire O to the field magnet O to the common connecting wire 8, where it sub-divides between the field magnets F and G in parallel, returning over section wires F and G to segments F and G in the transmitter and through the contact maker to the inner negative segment and to the negative wire TBB.

All the field magnets being wound alike, opposite magnetic poles are induced in the inner ends of the magnets O and F and G, respectively, and since opposite poles are induced in the two ends of the pivoted magnet, it is caused to assume a position indicated by the line 6.

Tracing out the connections for any other position of the contact maker will show that one field magnet and two diametrically opposite ones are always energized and the movable magnet will always take a position such that one pole of it is in line with one and the other pole is midway between the other two.

In the actual transmitter, the contact segments are arranged as arcs or segments one over the other and the contact maker is vertical.

Gun-Firing System.

The gun-firing system consists of separate circuits, fore and aft for the turret guns and starboard and port for the broadside guns. The current supply is from local switches on the interior-communication switchboard, fed from gun-firing motor generators, power for which is obtained from a switch on the interior-communication board. Provision is made at each gun for transfer to the local firing battery for current supply.

The system is energized with alternating current of 125 volts, single phase, 60 cycles, with a ¼ kw. transformer in watertight case at each gun. The secondary voltage required at the guns is 15 volts. "Delayed action coils" can be thrown into circuit for firing any one of the guns, so that any gun can be fired at predetermined intervals after the others.

Rotary Converters and Transformers for Gun-Firing.—The rotary converter and transformer is a self-contained unit weighing about 70 pounds, and consists of a small rotary converter, transformer, and multipolar switch mounted inside a watertight case. It provides a low-voltage alternating current for gun-firing derived by transformation through the rotary converter and transformer from the lighting and power supply circuit. Commencing with the *Arizona,* current will be supplied only from the lighting system as the voltage of the power system has been increased from 125 to 240.

The rotary converter is specially designed for gun-firing circuits and has a laminated field core made of high-grade electrical sheet steel pressed into a drawn-steel shield or frame. The armature is drum wound with a commutator of large proportions and ample brush sections. Carbon brushes are used on both the commutator and collector ring ends. The shaft runs in annular ball bearings and both ends are enclosed by dust-proof covers. The brush rigging is of non-corrosive material.

The alternating current delivered to the transformer by the converter is of approximately 60 cycles frequency and approximately 80 volts potential.

The converter frame is insulated from the enclosing case in addition to the usual insulation.

The transformer consists of two separate windings mounted on a laminated iron core. The secondary firing circuit is entirely insulated from the primary circuit so that a short circuit or ground in the secondary will not ground or short circuit the supply circuit.

The primary winding of the transformer is arranged for approximately 80 volts and 60 cycles alternating current which is delivered from the slip rings of the rotary converter.

The secondary winding of the transformer delivers 10 volts on open circuit and the short circuit current is from 5 to 7 amperes, depending upon the contact resistance of the firing key, primer and firing circuit.

The transformer is so constructed as to permit the secondary being short circuited without causing damage or overheating, or drawing but a small increase of current from the direct-current supply.

The entire transformer is embedded in an insulating compound so that it is entirely insulated from the enclosing case and the leads are held securely in position eliminating possibility of injury due to shock or vibration.

The case is of composition metal provided with bosses which are pipe tapped for Navy standard $\frac{3}{4}$-inch terminal tubes. The upper half is removable, exposing the entire rotary converter for inspection. The cover and switch handle are packed, making the device watertight and flame proof. The cut-out switch handle is on the outside of the case and a pointer is provided to indicate the "off" position, and positions for the available direct-current sources of supply.

The standard battleship installation provides one rotary transformer for each 2-gun turret and one for each group of broadside guns, provided the number per group does not exceed four. Three-gun turrets are provided with duplicate rotary converters. Portable storage batteries, as described in Chapter V, Vol. I, are used as the alternative method of gun-firing.

CHAPTER XVII.

SEARCH-LIGHTS.

A search-light consists essentially of an electric lamp placed at the focus of a mirror, which projects the light in a beam of parallel rays. The electric arc is the only type of lamp used for search-lights in the Navy, although it is proposed to employ incandescent lamps for the small search-lights used for signaling purposes.

Essential Parts.—Fig. 243 illustrates the General Electric Company 36-inch distant control search-light. C is the **distant controller**, which is purely mechanical. One control wheel turns the drum in azimuth through a series of gear trains, rods, and universal joints; and the other control wheel elevates and depresses the drum through similar mechanism. Distant control by means of electric motors has been tried and abandoned as less satisfactory than the mechanical type here described. B is the **base** which serves as the search-light foundation. It is hollow and contains the main-line switch, connection board, and the controller gearing. T is the **turntable** resting on roller bearings carried by the base. All electric circuits are completed through contact rings on the under side of the turntable, which bear on contact plungers in the base. This allows continuous rotation of the turntable without twisting of cables. A-A are the **arms** or **side rods**, carrying trunnion bearings in which is mounted the **barrel** or **drum** D. The drum carries the mirror and the lamp with its operating mechanism. The structure formed by the base, turntable, arms, and drum is called the **projector**. The front of the drum is enclosed by **front door strips** of glass, mounted in a grooved ring. The ballast resistance is mounted in a protected part of the ship below decks.

The drum may be disengaged from the pinions of the distant control gear and operated by means of handles at the back.

The above applies in a general way to all types of search-lights now in service, although in some cases the distant control is not fitted. The main differences between various types lie in the kind of lamp used and in the lamp control mechanism.

SEARCH-LIGHT LAMP.

Until recently the open carbon arc was used exclusively, but another type is used with the Beck search-light.

Requirements of a Search-light Lamp.—The essential requirements of a good search-light lamp are that it shall burn with an even brilliancy and remain at the focus of the mirror. These are not easy conditions to fulfill. The focus of the lamp being practically a point, it is essential that the source of illumination be very small, which eliminates the use of incandescent lamps

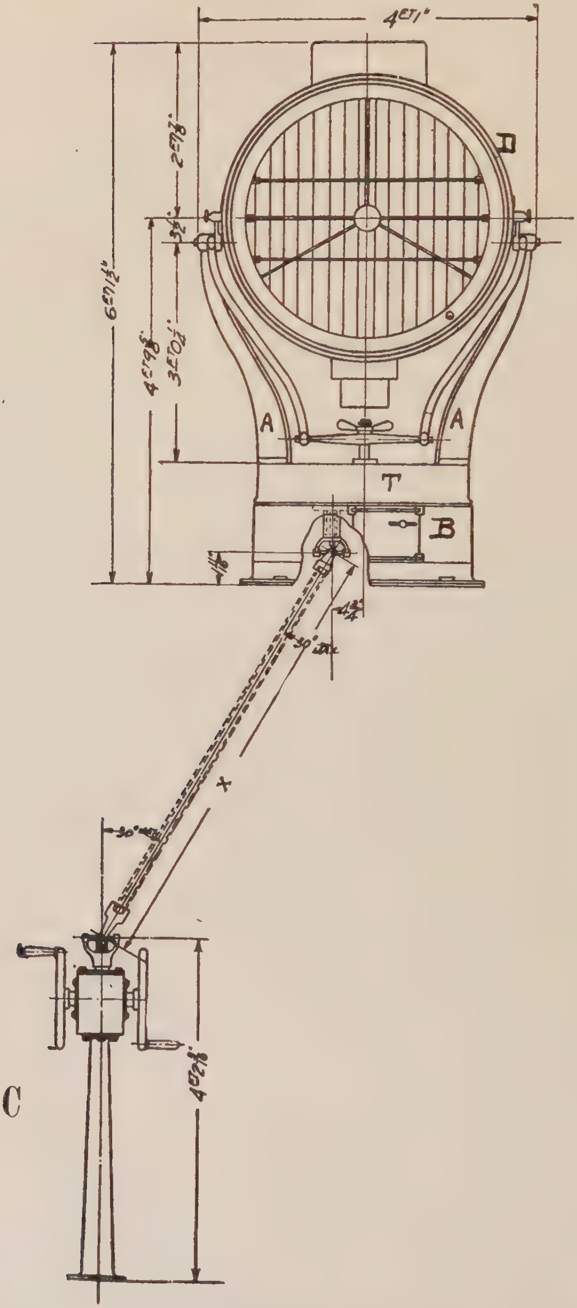

4FT 1"
2FT 7 3/8"
3 1/2"
6FT 7 1/2"
4FT 9 5/8"
3FT 0 1/2"
D
A
A
T
B
1 1/8"
30° MAX
X
30° MAX
C
4FT 2 7/8"

FIG. 243.—36-Inch Search-light, Distant Control. General Electric Co.

for high-power search-lights. The arc lamp is the best source in that its intrinsic brilliancy is high but, owing to the fact that the electrodes waste away, it requires more or less complicated mechanism to keep the light in focus. The objects sought in the various designs are a source of light of small area and intense brilliancy which will automatically remain in focus.

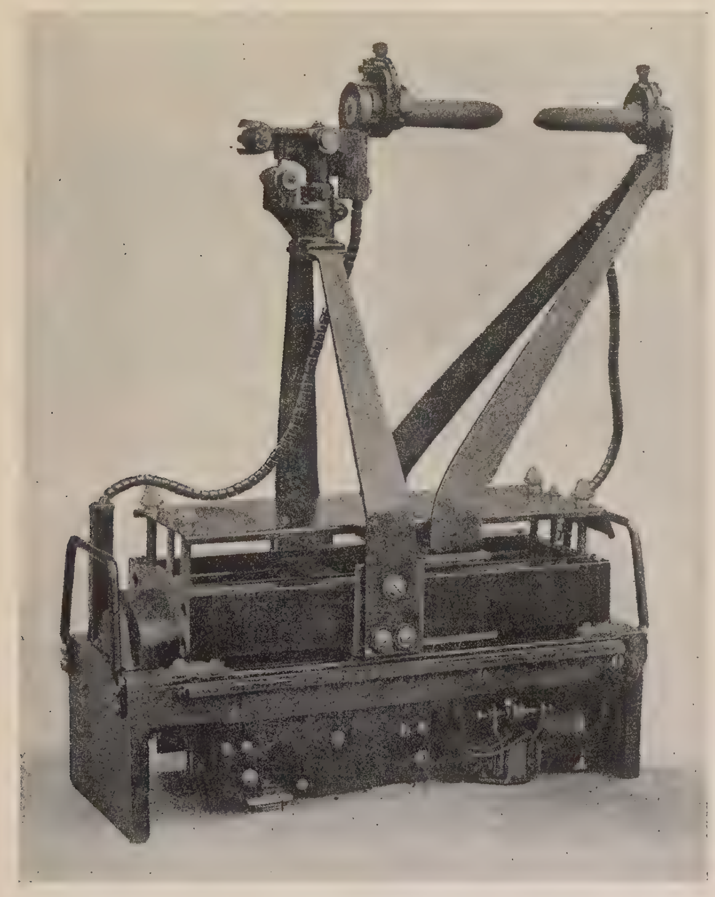


FIG. 244.—Lamp Mechanism. Carlisle and Finch 30-Inch Search-light.

THE OPEN-CARBON ARC SEARCH-LIGHT.

A carbon arc search-light lamp with ratchet feed—an old type—is described in Volume I. In more modern types motor feed is used, as illustrated in the two lamps described below.

Carlisle and Finch 30-Inch Search-light Lamp.

Fig. 244 shows the general appearance of the lamp mechanism. This is mounted in the drum. The entire working part may be moved forward or backward in the containing box by means of a screw spindle operated by an external hand wheel. This permits setting the arc in the focus of the mirror. Carbon electrodes with soft cores are used, the larger being made the positive because it burns more rapidly. The life of a pair of carbons is about seven hours.

Circuits.—Fig. 245 is an elementary diagram of the circuits. From the circuit switch at the switchboard a negative lead goes direct to the feeding motor, while the negative lead to the electrodes passes through the rheostat. The rheostat is composed of fixed ballast resistance and, for adjusting the arc voltage, a variable resistance mounted on or near the search-light panel in the distribution room.

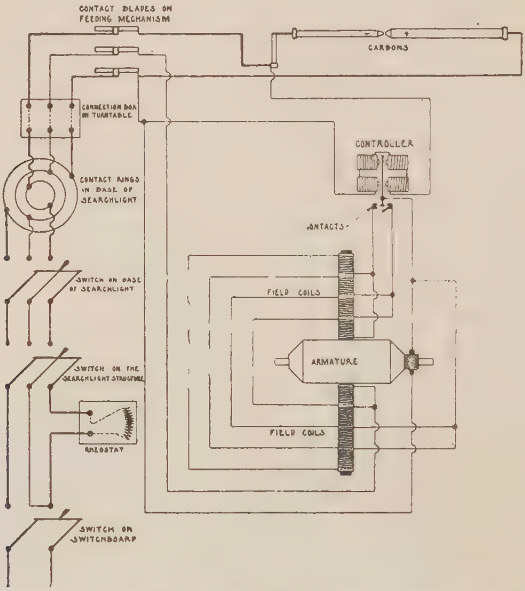

CONTACT BLADES ON FEEDING MECHANISM
−
+
CARBONS
CONNECTION BOX ON TURNTABLE
CONTROLLER
CONTACT RINGS IN BASE OF SEARCHLIGHT
CONTACTS
SWITCH ON BASE OF SEARCHLIGHT
FIELD COILS
ARMATURE
SWITCH ON THE SEARCHLIGHT STRUCTURE
RHEOSTAT
FIELD COILS
SWITCH ON SWITCHBOARD

FIG. 245.—Elementary Wiring Diagram. Carlisle and Finch 30-Inch Search-light.

From the rheostat the feeders lead through the 3-pole cut-out switch at the search-light, the turntable contact rings, the connection box and the contact blades (or shoes). The latter form the sliding contacts between the lamp mechanism box and the mechanism itself. This much of the circuit is typical of all search-lights.

Operation.—The carbon holders are carried on screw spindles operated by the motor shown. The motor is geared to the spindles in such a way that when it rotates in one direction the carbons approach each other, and when it rotates in the other direction the carbons separate. The motor is bipolar, each field core being wound with four coils in series with the armature. The controller shown in the diagram controls the direction of rotation of the motor. The actuating coils are in parallel with the arc, so the actuating current varies as the voltage across the arc. The movable middle contact is held against the left-hand fixed contact by a spring when the voltage across the arc is below normal. When the arc voltage is normal, the movable contact

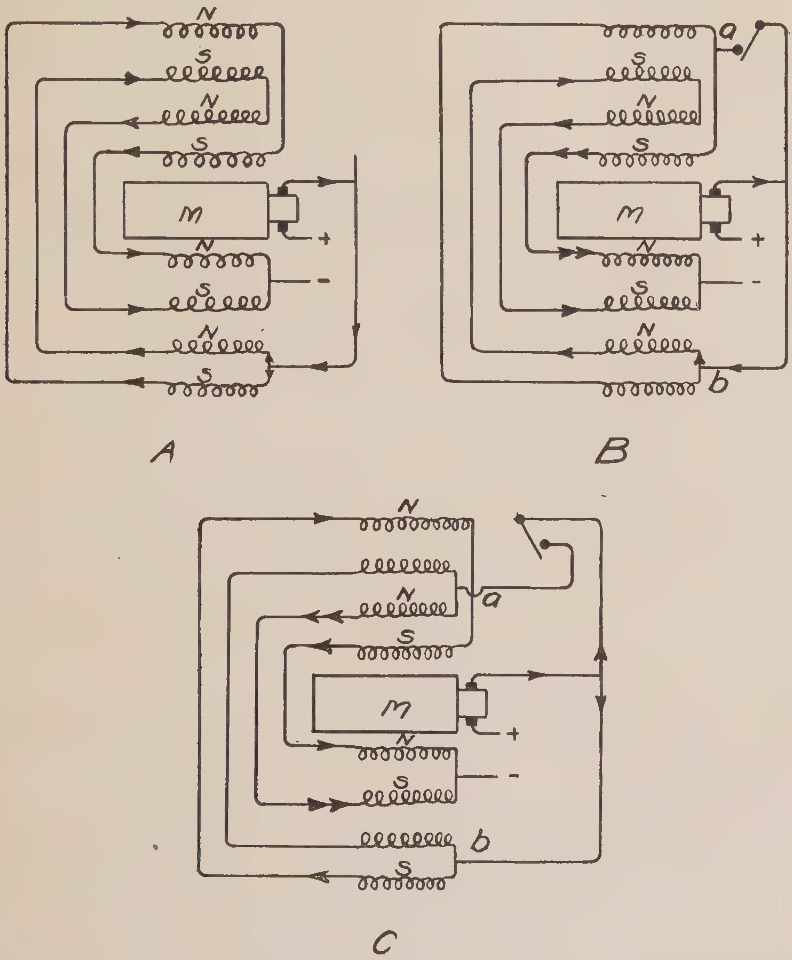


FIG. 246.—Diagram of Field and Armature Circuits of Feeding Motor. Carlisle and Finch 30-Inch Search-light.

is pulled away from the fixed contact to the position shown in the diagram. When the arc voltage is above normal, the movable contact is pulled against the right-hand fixed contact. The resulting actions may be followed from Fig. 246, which is a simplified drawing of the armature and field circuits of Fig. 245.

In A (Fig. 246) the arc voltage is normal and the controller is "open." Since no current flows through the controller, that much of the circuit is omitted. As illustrated, the field coils of each field core form two north poles and two south poles, so there is no flux and no movement of the armature, although the armature current continues to flow.

In B (Fig. 246) the arc voltage is below normal and the controller closes the circuit to the left-hand contact. The points *a* and *b* are at the same potential, so no current flows in the two field coils that connect these points. As illustrated, there is formed on the upper field core a weak north and a weak south pole which cancel one another, and one strong south pole. On the lower field core the magnetic effects of two poles cancel each other, leaving one strong north pole. The armature rotates and feeds the carbons apart.

In C (Fig. 246) the arc voltage is above normal. As illustrated, this reverses the effective polarity of the field coils and the motor reverses and feeds the carbons together.

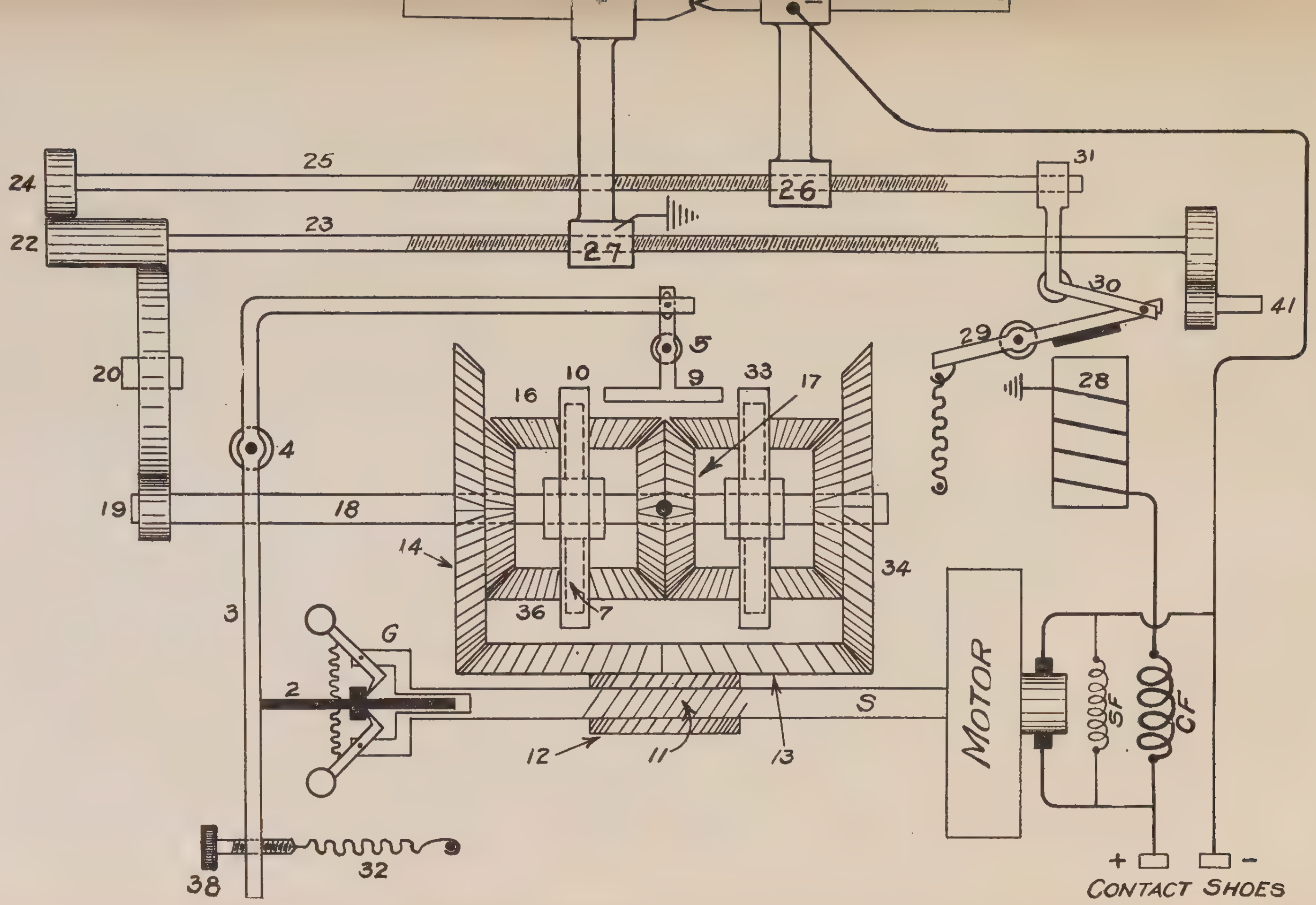
The feeding mechanism in addition to maintaining the arc length also strikes the arc. When the circuit switch is closed, no current flows if the carbons are separated. The full-line voltage then exists across the arc and the motor feeds the carbons together until they touch. This causes a big drop in the arc voltage and the motor feeds them apart, striking the arc. When the arc is of proper length, the motor automatically stops. As the carbons burn away, the arc lengthens and the voltage rises, causing the motor to feed the carbons together again.

General Electric Company 36-Inch Search-light Lamp.

This differs from the Carlisle and Finch lamp in having a non-reverse, compound-wound feeding motor, a mechanical controller which controls the direction of feed of the electrodes, and in having a separate electromagnet for striking the arc.

Circuits.—The circuits up to the lamp are as before described, except that the motor is in series with the arc and so requires only two feeders. Current enters at the positive shoe (Fig. 247), flows through the motor armature and shunt field to the negative shoe. In parallel with the armature, current flows through series field CF, starting magnet 28, to a ground on the lamp frame. The positive carbon holder is also grounded to the lamp frame. The current flows through these two grounds, across the arc, and back to the negative line through the flexible conductor.

Operation.—Suppose that when the cut-out switch is closed the carbons are in contact as shown. A heavy current flows through the arc circuit and the starting magnet 28 attracts the armature 29 which slides the negative feed screw to the right by means of the bell-crank lever, striking the arc.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14
34
36
7
3
G
2
S
12
11
13
MOTOR
SF
CF
+
-
CONTACT SHOES
38
32

FIG. 247.—Diagram of Lamp Mechanism. 36-Inch Search-light. General Electric Co.

The motor runs continuously. The motor shaft S, by means of the worm 11 drives the worm wheel 12 which is part of the bevel pinion 13. Pinion 13 drives the two bevel pinions 14 and 34. Pinion 14 drives the two pinions 16 and 36. These two are mounted on and are free to revolve about shaft 7, which turns freely about shaft 18. Consequently, shaft 7, if not prevented from doing so, revolves about shaft 18 and the pinions 16 and 36 roll on pinion 17. A circular clutch 10 is controlled by the arm 9. When 9 is forced against 10 the shaft 7 can no longer revolve about the shaft 18, and the pinions 16 and 36 drive pinion 17 which is pinned to the shaft 18. Shaft 18 drives the feed screws 23 and 25 through the gear train shown. If 9 engages with the clutch 33, shaft 18 is driven in a similar manner, but in the opposite direction by the pinion 34.

As the carbons burn away the current through the arc decreases and weakens the series field of the motor. This causes the motor to increase in speed, expanding the centrifugal governor G which presses outward the spindle 2 which in turn forces outward the arm 3 which, through a system of bell-crank levers pivoted at 4 and 5, locks the clutch 10. This as previously described, causes the motor to drive the feed screws 23 and 25. The carbon carriers are connected to the feed screws by nuts, and the revolution of the feed screws causes the carbons to approach each other. This increases the arc current, the series field becomes stronger, the motor slows, the governor contracts, the clutch is released and the carbons cease to feed. If the arc becomes too short, the increase of current through the series field still further slows the motor, the governor contracts still more and clutch 33 is locked. This reverses the direction of rotation of the feed screws and the carbons are separated.

The arc voltage is adjusted by means of the screw 38 which controls the tension of spring 32. Increasing the tension increases the arc voltage, because a greater motor speed is then required to expand the governor weights.

The gear 20 can be disengaged by moving a lever and the feed can then be controlled by hand by means of an open-end wrench applied to the end of the shaft 41.

Disadvantages of the Carbon Arc Search-light.—In the usual types, such as those described, there is no positive means of holding the arc at the focus. The gearing of the carbon holders is so arranged that the rate of feed of each electrode is approximately equal to the rate at which it wastes away; but carbons are somewhat irregular in their rate of burning and it is necessary to readjust the focus by the hand-focusing gear from time to time while the lamp is in use. The carbons are horizontal and, therefore, tend to burn faster at the top than at the bottom, causing "wandering" of the positive crater. Some projectors have been fitted with a device for rotating the positive carbon to prevent this, the apparatus being in some cases motor driven and in other cases operated by hand. Since the source of light is the positive crater, it must be located so as to shine directly into the mirror, and this necessitates placing the negative between the mirror and the positive, which cuts off part of the light.

THE BECK SEARCH-LIGHT.

In the Beck search-light some of the faults of the open-carbon arc light are corrected. The feeding mechanism is so arranged that the crater of the positive electrode is kept at the focus of the mirror, while the arc length is maintained by an independent feeding mechanism for the negative electrode. Both electrodes are constantly rotated by means of a motor, to keep the arc centered. The electrodes are of carbon, the positive having a core of rare earth of extremely high melting point. Both carbons are bathed in hydrogen vapor supplied by an alcohol spray. Access of oxygen is thus prevented and, in consequence, the electrodes may be maintained at a very high temperature without causing rapid combustion, much higher than in the case of the ordinary search-light. In consequence, the positive crater is very deep, rather small in cross-section and intensely hot. This not only gives a greater light from a smaller source than in the case with the ordinary open arc, but also gives a light which is rich in violet rays. The eye is more sensitive to violet than to red light when the intensity of illumination is weak, so the Beck lamp gives not only more light, but also light which is better suited for illuminating distant objects.

Construction of the Lamp.

Fig. 248 illustrates the general appearance of the lamp. The pedestal that supports the positive carbon holder is stationary. The pedestal that supports the negative carbon holder moves when striking the arc, but is stationary at other times.

Rotating Mechanism.—A motor in the lamp housing, by means of gear trains and connecting rods rotates both carbon holders at a constant speed. An emergency hand rotating device is provided.

Feeding Mechanism.—The carbons are carried in roller bearings, movement of which feeds the carbons through the holders. A star wheel below each holder controls the feed. A star wheel is attached to the revolving holder and, consequently, rotates. The control rods may be raised so as to engage with the star wheel once during each revolution of the holder. The higher up the control rod is the longer it remains in engagement with the star wheel. When the star wheel is held by the control rod, it causes the roller bearings to turn and feed the carbons. Thus the rate of feed is determined by the height of the control rod.

The negative control rod is mechanically adjusted by the search-light attendant so as to give approximately the proper rate of feed. The position of the negative carbon is not of great importance and is regulated by observing its position through a ground-glass window in the drum.

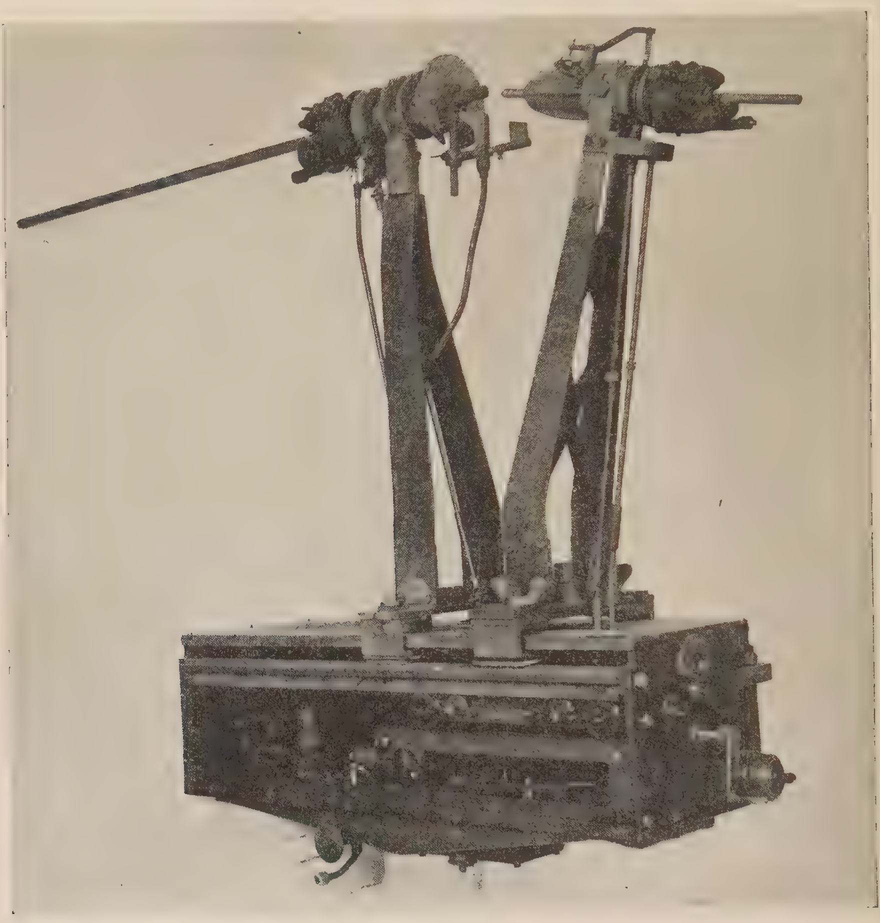

FIG. 248.—Lamp of Beck Search-light.

The positive carbon, being the principal source of light, must be held accurately in focus. A thermostat is so arranged that the heat rays from the positive crater are reflected against it by a special mirror whenever the crater leaves the focus. The thermostat is a metallic block which when heated by the radiation expands and closes the circuit to an electromagnet which raises the positive control rod, causing the positive carbon to feed toward the negative. When the crater is again in focus, the reflected radiation no longer falls on the thermostat, the block contracts, the electromagnet is de-energized and feeding ceases.

Vaporizer.—Alcohol is carried in a tank in the drum. It flows by gravity through a rubber tube to electric heating coils which vaporize and superheat it. The vapor is discharged through two nozzles and surrounds the electrodes, preventing oxidation.

Ventilation.—A motor-driven exhaust fan removes from the drum the gases and smoke given off by the arc.

Striking the Arc.—A motor is geared to the negative carbon-holder pedestal. This motor is connected across a Wheatstone mesh, one arm of which is formed by the arc (see Fig. 249). If the carbons are separated when the circuit switch is closed, no current can flow through the arc, so current flows down through the motor, feeding the negative electrode toward the positive. When the carbons touch, the resistance across the arc becomes very small and current flows up through the motor, reversing its direction of rotation and drawing the negative carbon away from the positive. When the arc length is normal, the mesh is balanced and no current is supplied to the motor. But if the arc goes out, the motor immediately becomes operative and strikes the arc again.

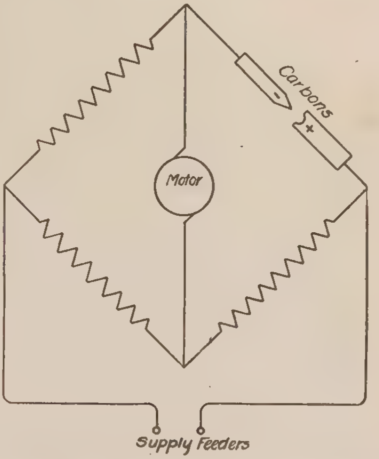

FIG. 249.—Diagram of Circuits of Beck Search-light Lamp.

The Electrodes.—The negative electrode is of carbon. The positive is of carbon cored with rare earth which may be raised to a very high temperature without vaporizing. The positive carbon is larger in cross-section than the negative, and is very long. It projects through the glass door in the front of the drum, being protected by a tube supported from the outside of the drum. Both carbons are much smaller than in the usual carbon arc and carry a much heavier current, to which is due the unusually intense heat. The positive carbon is horizontal, but the negative is inclined at an angle of 14° with the horizontal and, consequently, cuts off but little of the light.

CHAPTER XVIII.

SIGNALING APPARATUS.

Night Signal Set.—The night signal set consists of four pairs of lanterns arranged in a vertical row; one lens of each pair is white and the other red. Each lantern is made up of seven 10 candle-power, 12-volt lamps, of which four are in each red lens and three in each white lens. These lamps are fed by nine conductors; eight positive leads for the eight lanterns and a common return. The lanterns are operated by means of a watertight key board carrying 30 operating switches. Each switch is held open by a spiral spring, and is closed by pushing a plunger. Each of the eight leads to the lanterns terminates in a bus bar at the key board. Each operating switch, when depressed, makes contact with one or more (never more than four) spring contacts attached to the bus bars. For example, the switch marked A, when depressed, connects the positive leg of the ship's circuit to the red lamps of the upper lantern and the white lamps of the second lantern from the top. Small shunt resistances allow a current to flow through the lamps at all times, causing them to retain a dull glow; this increases rapidity of operation, since otherwise an appreciable time would elapse between pressing the key and full brilliancy of the lamps. A pulsator switch is provided to make and break the circuits to both upper lanterns. To make a signal with the upper light pulsated, the proper signal key is depressed and the pulsator switch rapidly opened and closed. The key board is fitted with a hinged watertight cover and a pilot lamp controlled by a spring switch which is turned on automatically when the cover is raised. This lamp serves to illuminate the key board and to indicate that the circuit of the set is energized.

Blinker Signals.

This appliance is used for signaling by Morse code and consists of two lanterns and two controllers. The lanterns are secured respectively to each end of the signal yard. One controller is located on the starboard side of the bridge, the other controller on the port side. Diagram of connections is shown in Fig. 250.

The controller consists of a composition metal box in which is mounted a telegraph key and two single-pole switches, one for each blinker light. The box is secured to the bridge rail and is fitted with a hinged cover.

The hinge blocks of the two single-pole switches are joined together and electrically connected to the telegraph key; the jaw blocks of each switch connect to its respective blinker light.

Current is supplied from a distribution box to the connection box by a leaded and armored cable. From the connection box a lead of 4-conductor cable, leaded and armored, is taken to both controllers via a 25-ampere double-pole switch, and then up the cage mast to two receptacles under the signal yard. A lead is taken from these receptacles to the lanterns.

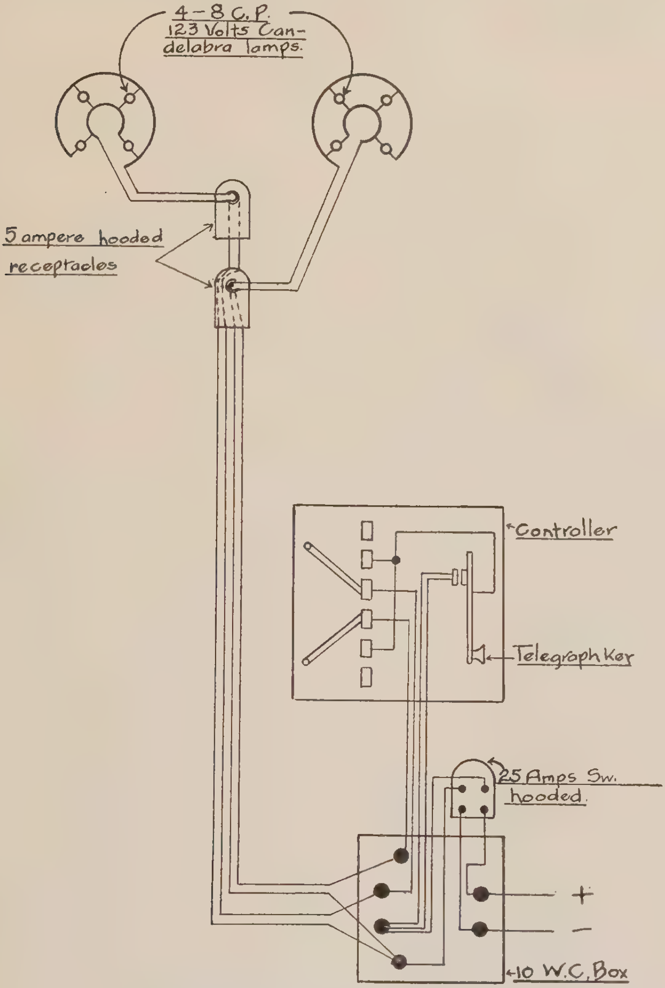
4-8 C.P.
123 Volts Candelabra lamps.
5 ampere hooded receptacles
Controller
Telegraph Key
25 Amps Sw. hooded.
+
−
10 W.C. Box

FIG. 250.—Blinker Signals, Diagram of Connections.

The armored sheaths of all the above leads are grounded at their terminal tubes; this is done to prevent the circuit from being affected by induction from the radio telegraph.

Operation.—The 25-ampere double-pole switch being closed and the telegraph key depressed, the circuit is as follows: From positive source of supply, through the positive side of double-pole switch, through telegraph key to single-pole switch, thence through receptacle to blinker light, back through receptacle, through negative side of switch to negative source of supply.

Two-Arm Hand Semaphore.

The apparatus consists in general of three parts, viz., a pedestal, a lower column containing the bearings, and an upper column containing the signal arm and mechanism.

The pedestal is of cast iron, mounted on a hickory base block. In this base is a tool steel ball race, fitted on a manganese bronze flange, bushed into the pedestal. At the crown of the pedestal is a manganese bronze bush for the roller bearings.

The lower column is journalled into the pedestal by means of a composition base, and a manganese bronze flange near its upper end. In the base, the upper tool steel ball race is fitted. The upper journal or flange revolves on 12 cold-rolled steel rollers, suitably secured in a cage. Both upper and lower bearings have felt wipers saturated in oil, fitted in grooves to exclude dirt and prevent corrosion of bearings.

Immediately above the pedestal, the lower and upper columns (which are of brass tubing) are joined by a sleeve, permanently attached to the latter and secured to the former by two bolts. When coaling ship, and at other times as may be necessary, if these bolts are withdrawn, the entire upper section of the semaphore containing all the signaling apparatus operating levers may be unshipped.

Near the top of the upper column, the signal blades are attached to brackets, and can be rotated. The

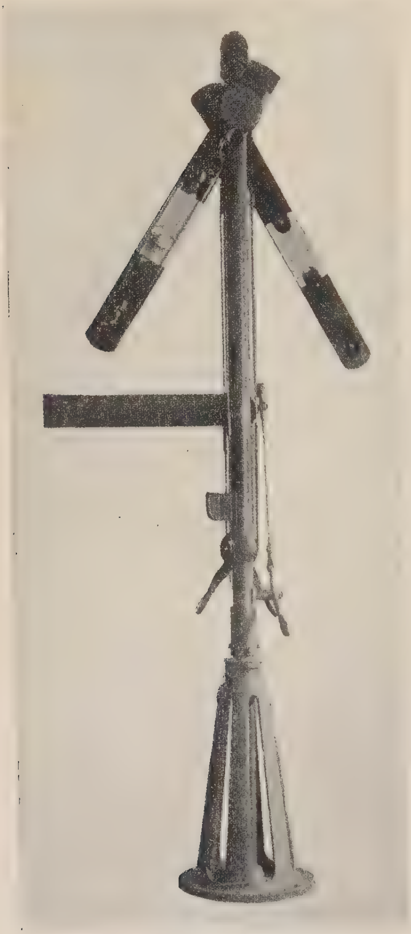

FIG. 251.—Two-Arm Hand Semaphore, Type D.

pivot ends of these blades are fitted with balanced weights and contact boxes. In the latter are concentric contact rings, revolving against carbon fingers attached by an insulated yoke to the arm bracket, and thus conveying current to the lamps (of which there are three 32 candle-power per blade). These blades are revolved by means of hand levers at a convenient height, operating through sprockets and chains.

A blind arm, pivoted at a point below the signal arms, is operated by means of a hand lever and connecting rod and can be moved through an arc of 90°.

At the top of the column there is a 32 candle-power lamp within a red globe and standard guard. This marks the center of the apparatus when signaling by night, and a blind or shade enables this light to be thrown only in a direction desired for signaling.

Suitable pins and holes in the pedestal and roller journal, as well as in the levers and brackets, provide means for locking both column and signaling mechanism, thereby preventing motion when the apparatus is not in operation.

Connections (Fig. 252).—Current is led up to the base in standard cable, the leads being attached to terminals in an insulating base block secured in the pedestal. This base block contains contact rings, over which spring contact fingers rotate. These fingers are secured to the column base, revolving with it. From these fingers a twin conductor is led through a standard stuffing tube, and through the lower column, and terminates in two contact rings which are attached to an insulating block at the top, and fingers at this point continue the circuit to the upper column, and also provide the break when the upper column is unshipped. From the upper fingers, a twin conductor leads to a 25-ampere double-pole switch on the outside of the upper column. This switch controls the lights. From the switch, a twin conductor is continued to top of column direct to the red light, and in line with the pivot point of the signal arms, the conductor is tapped and leads taken to the carbon fingers in the contact boxes on the arms. The lamps on the arms feed from the insulated contact rings in these contact boxes.

12-Inch Search-light (for Signaling).

This search-light is of the hand-control type. The projector can be trained vertically or horizontally by means of handles on the sides of the drum. A star wheel mounted on the trunnion acts as a locking device by means of which the projector drum may be held at any desired angle.

Mirror.—The mirror is of the Mangin type, in which the two surfaces are paraboloids of different focal length, so proportioned that the reflection and refraction of the glass projects the rays of light in a parallel beam when the arc is in the focus of the mirror.

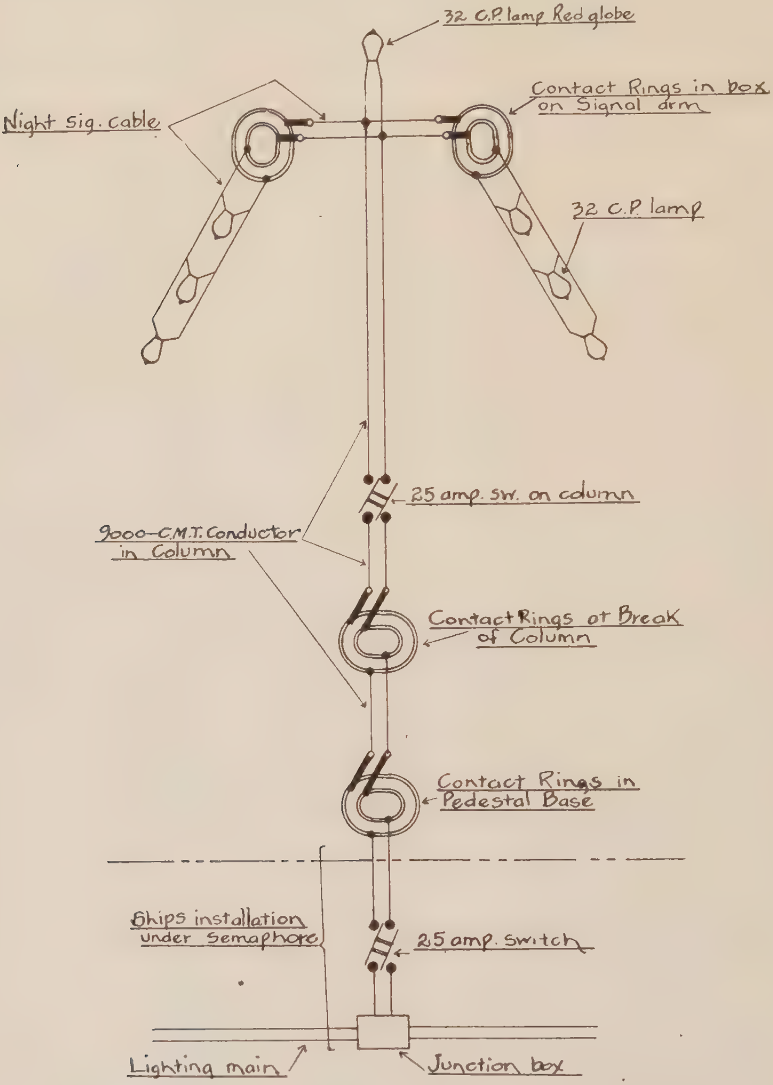
32 C.P. lamp Red globe
Contact Rings in box on Signal arm
Night sig. cable
32 C.P. lamp
25 amp. sw. on column
9000-C.M.T. Conductor in Column
Contact Rings at Break of Column
Contact Rings in Pedestal Base
Ships installation under Semaphore
25 amp. switch
Lighting main
Junction box

FIG. 252.—Hand Semaphore, Diagram of Connections.

To allow for expansion due to heat, and to prevent injury from concussion, the mirror is flexibly mounted in a metal ring, which can be readily removed from the drum.

Lamp.—The lamp is of the horizontal type and automatic. The feeding is accomplished by a positive screw-feed ratchet, driven by an electromagnet. Each carbon is fed automatically at such a rate as to keep the arc in focus until the carbons are consumed. The positive carbon clamp is adjustable in both planes, so that the carbons may be kept in perfect alignment at all times and burn to the best advantage.

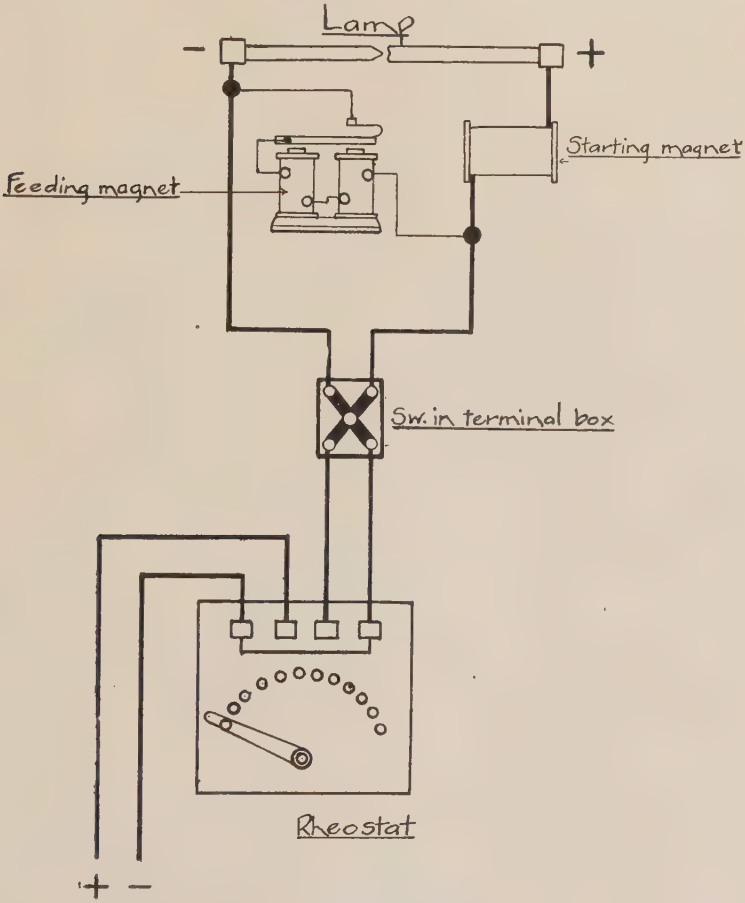

FIG. 253.—12-Inch Signaling Search-light.

Rheostat.—A rheostat is provided so that the current can be adjusted to its proper value in the event of variation or change in the circuit voltage.

General.—The projector drum is balanced on its side rods. The turntable is provided with two conductor rings, against which current-carrying plungers are pressed from below by springs, thus allowing drums to be revolved indefinitely in either direction without twisting of feed wires.

The projector drum is provided with a front door made up of plate glass strips set in a metal ring readily attachable to or removable from the drum.

The signaling shutter, of the Venetian blind type and easily removable, is fitted on the projector front door.

An operating lever is installed on each side of signaling shutter; this arrangement allows the operator to signal from either side of projector.

A telescope is secured to the side of projector drum in such a manner as to be easily removed, and when in position the axis of the telescope will be parallel with the beam of light.

An elementary wiring diagram is shown in Fig. 253.

Automatic Speed-Light Controller.

Function.—A speed light consists of a red lantern and a white lantern by means of which the speed of the ship is indicated. Modern vessels usually have three speed lights, one at the fore truck, one at the main truck, and one on the after side of the mainmast; the last has a screen so arranged that the light shows through only a small angle. The automatic controller is so arranged that the lanterns at any one of the three stations may be used to make any of the following indications:

White, steady	Ahead standard speed.
White, double flash....	Ahead ⅔ speed.
White, single flash....	Ahead ⅓ speed.
Red, steady	Stop.
Red, single flash......	Astern slow speed.
Red, double flash.....	Astern full speed.

The signals may also be given by a hand-operated pulsator.

Construction.—Speed-light controllers of several types are in use. The Cory machine here described shows the principles involved in most of them.

In Fig. 254 the mechanism in the case on the left-hand side is the device that causes the lights to flash. It consists of a shunt-wound motor geared to two cam wheels. The motor runs at constant speed and the gear train and cam wheels are so arranged that one wheel closes a circuit for one second and opens it for four seconds during each revolution, thus causing single flashes in a lamp connected in the circuit. The other cam wheel has two projections and causes two flashes of ¾ second duration with an interval of ½ second between them during each revolution, the time of one revolution being five seconds.

The controller itself is shown on the right of Fig. 254. The functions of the two switch arms are evident from the illustration. The two black circles marked R and G are pilot lamps. The red pilot lamp R is in series whenever a red speed light is turned on and lights only when the circuit is complete. The green pilot lamp indicates the operation of the white speed lights. P is the hand pulsator.

Circuits.—Fig. 255 is an elementary diagram of the circuits. F is the switch controlled by the large arm shown in Fig. 254, and S is the selective switch by means of which fore truck, main truck, or screened light may be connected to the controller. The solid black parts of the arm of switch F are conductors. The arm of switch S is shown separately for the sake of clearness. M is the motor, *c, c, c* are the projections on the two cam wheels, and P is the hand pulsator.

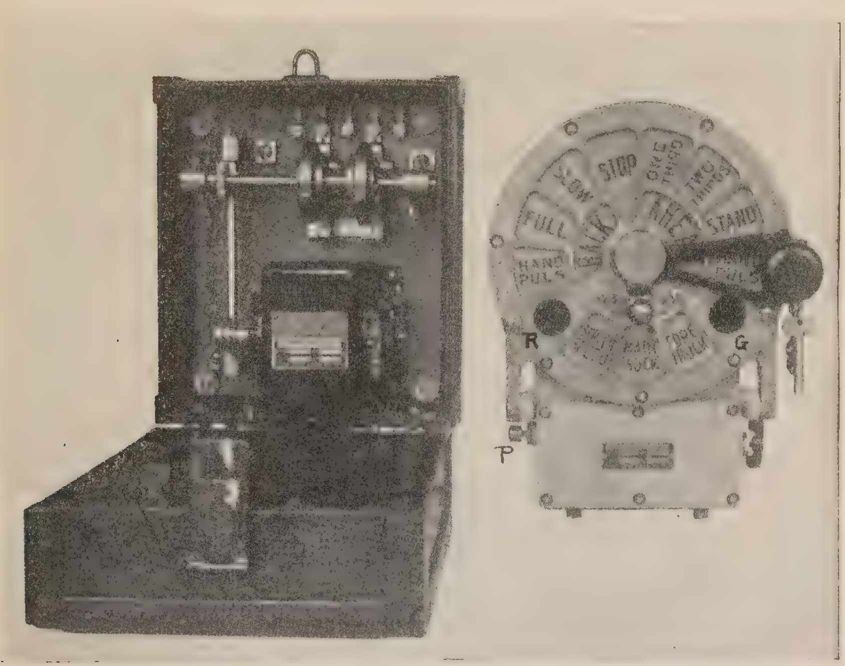

FIG. 254.—Automatic Speed-Light Controller.

As actually constructed the two circular switches S and F are concentric.

Operation.—Suppose the switch F set as shown (which is "full-speed astern" position), and the arm of the selective switch set vertically so that the main truck light is in circuit. Current flows from +L, through the motor, to segment M′ at F, to segment −L, the negative line. The spring switch A is closed twice in every revolution of the cam wheel, and through it current flows to segment AR (of switch F), then to segment R, through red pilot lamp to segment R (of switch S), across the inner switch arm, to red truck light, across center switch arm, to segment −L, to negative line.

If the arm of switch F is moved clockwise to segment BR, the motor circuit is the same as before, but the lamp circuit is now completed through spring switch B and single red flashes are given.

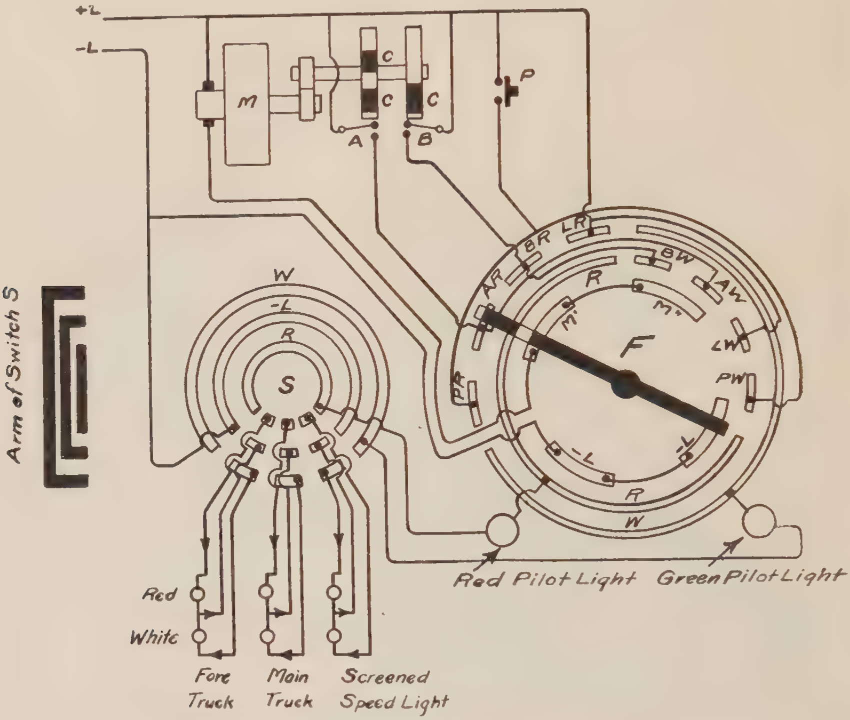
+L
−L
M
C
C
C
A
B
P
Arm of Switch S
W
−L
R
S
LR
BR
AR
BW
R
M''
M'
AW
LW
F
PW
PR
−L
−L
R
W
Red Pilot Light
Green Pilot Light
Red
White
Fore Truck
Main Truck
Screened Speed Light

FIG. 255.—Wiring Diagram, Automatic Speed-Light Controller.

If the arm of switch F is moved to segment LR (the "stopped" position), it leaves the segment M′ and the motor stops. The light circuit is then completed through segment LR, giving a steady red light.

If the arm of switch F is moved to segment BW, the motor circuit is closed through segments M″ and −L. The lamp circuit is now from +L, through spring switch B, to segment BW, to segment W (at switch F), through green pilot light, to segment W (at switch S), across the outer bridge of the arm of switch S, to white truck lamp, and back to the negative line. This is the "ahead one-third" position.

If the arm of switch F is on segment PW, the motor is stopped and the white light circuit is then completed through the hand pulsator P.

The Submarine Signal System.

This consists of a bell suspended under water which, when struck by a clapper, transmits its vibrations to the water. These may be picked up at a limited distance by a microphone receiver. The code used is Morse, a single stroke of the bell corresponding to a dot, and two strokes in quick succession corresponding to a dash.

The mechanism of the bell is very simple, the clapper being actuated by compressed air or an electromagnet.

The receiver consists essentially of a small metal box, one side of which is formed by the underwater plating of the ship. The receiver box is filled with salt water in which is suspended a microphone, consisting of two carbon electrodes, one fixed and the other attached to a diaphragm. The diaphragm is in contact with the water with which the box is filled. A telephone circuit is completed through the microphone.

The operation is as follows: The vibrations of the bell, or of the Fessenden oscillator, which is described later, cause longitudinal waves in the water. These waves impinge on the side of the receiving ship and cause vibrations of the skin plating. These vibrations are transferred to the water in the receiver box, setting up longitudinal waves. These impinge on the microphone diaphragm which vibrates in resonance with them. This alternately loosens and tightens the contact between microphone electrodes, causing pulsations in the telephone current. Thus each stroke of the bell is heard in the telephone receiver.

The reason for suspending the microphone in a tank instead of directly in contact with the sea water is that the microphone must be made very sensitive to respond to the weak vibrations it receives and, if hung over the side of a ship, would be rendered inoperative by the relatively large change in pressure caused by a change of a few feet in depth. Contained as it is, the water pressure is small and constant.

The Submarine Signal Set as a Direction Finder.—As actually installed, the receiving set consists of two receiver boxes, located below the water line, one on each side of the ship near the bow. If the sending station is directly ahead or astern, the sound waves in the water act with equal force on each receiver. If it is not in line with the vessel, the waves act more effectively on the receiver which is on the side from which the waves are coming. This principle is made use of as follows: A single telephone circuit is provided. This has a receiver for each ear of the operator, but these are in series and both are connected to but one microphone at a time. A switch is provided to connect the telephone to either starboard or port microphone. Suppose a ship to be in the vicinity of a fixed sending station, such as a lighthouse or a light ship. The bell at the sending station makes continually a signal consisting of a conventional series of strokes, this signal serving to identify the station. To obtain the bearing of the ship from the station, the operator on the ship listens in at the telephone, continually switching from one microphone to the other. If the sound is louder on one side than the other, the course of the ship is altered until no difference can be detected in the intensity of the sound from starboard and from port. The ship is then headed directly toward the sending station, and the bearing is determined.

The Submarine Signal Set as Bearing and Distance Finder.—If the sending station is equipped to send simultaneously signals by submarine bell and by fog horn or radio, the distance may also be determined. It is merely necessary to note the time between receiving the bell signal and the other signal, and to calculate the distance of the sending station from the known velocity of sound in water and its known velocity in air. Or, if radio is used, the velocity of propagation of electromagnetic waves may be assumed as infinite, and the interval between radio and bell signals multiplied by the velocity of sound in water gives the distance.

By this means it is possible to determine in a fog the identity of a fixed station, and the bearing and the distance of the ship therefrom.

If the direction-finding feature is to function properly, the two microphones used must be of the same sensitiveness; otherwise sound waves of equal intensity will be heard more loudly through one microphone than through the other. On this account, microphones are always furnished in pairs adjusted and tested to equal sensitiveness, and one of a pair cannot be used with one of another pair. To serve as a check on the indications, and to insure operation in case of damage to a microphone, two pairs (called A set and B set) are furnished with each receiving apparatus. A switch is provided so that either set may be connected to the telephone.

Wiring.—Fig. 256 is a diagram of the wiring of a complete outfit. Two dry-cell batteries are provided, one for the A set and one for the B set. The **receiver switch** is opened when the telephone receivers are on their hooks and closed when they are lifted off. Its function is to prevent waste of current when the apparatus is not in use. The double-throw switch on the left is marked "**stbd**" for one contact and "**port**" for the other. The other two switches are controlled by one lever and serve to connect either the A set or the B set of microphones in circuit. With the switches closed as in the diagram, the port microphone of the A set is operative. If the left-hand switch is thrown to the other contact, the starboard microphone of the A set is operative. If both right-hand switches are thrown to the right, the B set of microphones is cut in.

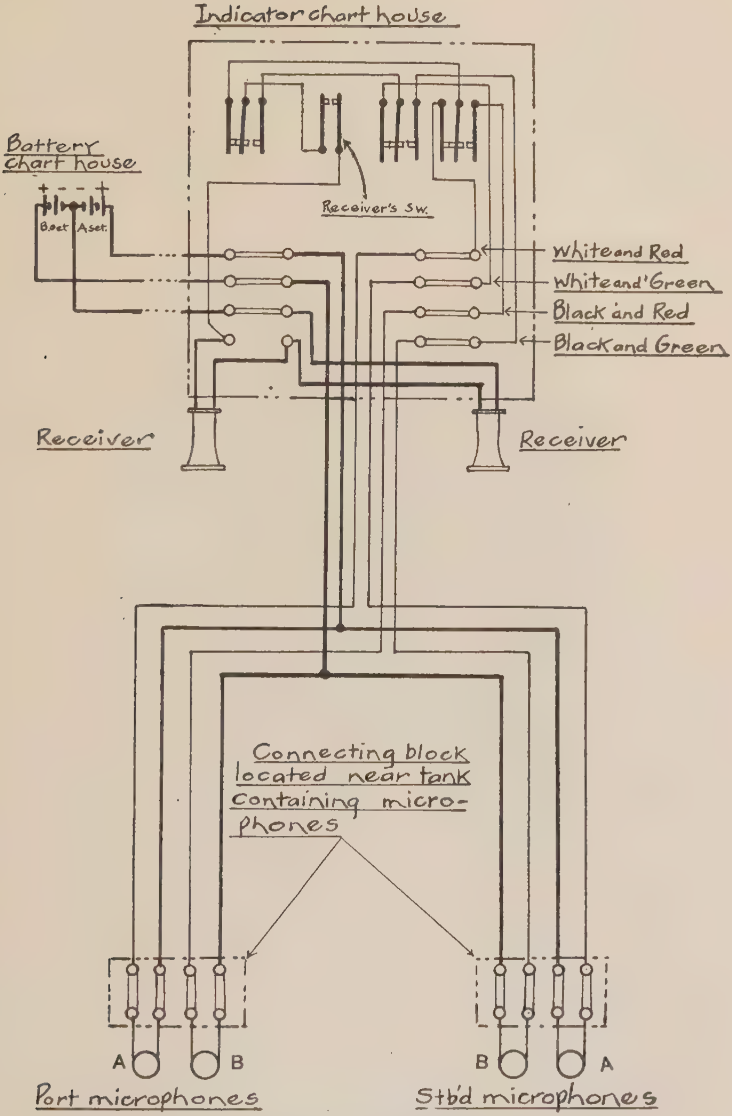
Indicator chart house
Battery chart house
+ - - +
B set
A set
Receiver's Sw.
White and Red
White and Green
Black and Red
Black and Green
Receiver
Receiver
Connecting block located near tank containing microphones
A
B
B
A
Port microphones
Stb'd microphones

FIG. 256.—Wiring Diagram of Submarine Signal System.

The Fessenden Oscillator.

One disadvantage of the submarine bell for signaling is that signals cannot be sent rapidly, since it is necessary to allow the vibrations of the bell to die out between strokes of the clapper. The Fessenden oscillator is designed to produce vibrations which, unlike those of the bell, are forced and, in consequence, strongly damped. Also the oscillator propagates its waves with greater energy than does the bell. Another advantage of the oscillator is that the same device which produces the sound is also a good detector of sound, comparable in sensitiveness with the microphones described in conjunction with the submarine bell.

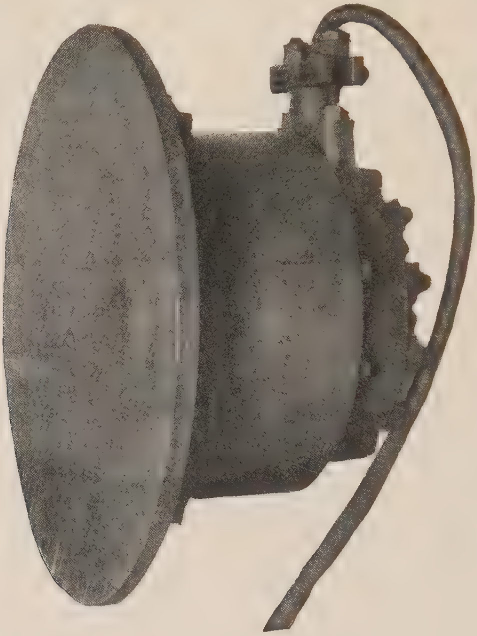

FIG. 257A.—Fessenden Oscillator.

In the oscillator a submerged diaphragm which is forced backward and forward with great rapidity sets up sound waves in the sea water in much the same manner that the diaphragm of a telephone receiver or of a phonograph sets up sound waves in the air. As sea water is almost incompressible a very great force must be used in moving the diaphragm to and fro. Also the loudness of the sound produced by the oscillator depends, in general, upon the area of the water acted upon by the diaphragm and upon the distance that the water particles are moved backward and forward. Consequently, a diaphragm of large diameter and great thickness is required.

Fig. 257A shows the external appearance of the oscillator, a diagrammatic sketch of which is shown in Fig. 257B. The diaphragm, which is indicated by the numeral 1, Fig. 257B, has a diameter of about 30 inches, which is to say that the area is about 300 times that of the diaphragm of an ordinary telephone receiver.

To produce the large force necessary to move the diaphragm, use is made of the principle that when a conductor carrying a current is placed in a magnetic field a force is exerted tending to move the conductor. The direction of the current is made to alternate rapidly, causing the conductor to be forced first in one direction and then in the other. The over-all depth of the oscillator is about 16 inches and its weight is about 1200 pounds.

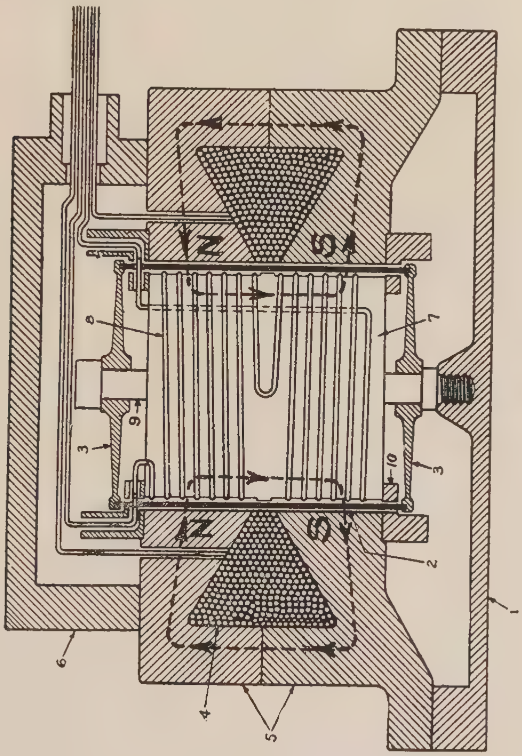

FIG. 257B.—Diagrammatic Sketch, Fessenden Oscillator.

The magnet which produces the field is indicated by the numeral 5 in the figure, and the movable conductor, which is a copper tube, is indicated by the numeral 2. Both the magnet and the conducting tube are shown in cross-section in the drawing. The magnet is in the form of a hollow cylinder and is of the iron-clad type, the single exciting coil, 4, being almost entirely surrounded by iron. When a direct current is passed through the exciting coil, the upper inside cylindrical surface of the iron becomes magnetized with one polarity, shown in the figure as north, and the lower inside surface acquires opposite polarity. The magnetic flux passes from the north pole through a very short air-gap to the iron cylinder, and from the cylinder passes to the south pole through another short air-gap. The path of the magnetic flux is shown roughly by the dotted lines. The iron cylinder serves to strengthen the magnetic field and to cause nearly all the lines of force in the gap to assume a direction perpendicular to the surface of the copper conducting tube. This copper tube, which is placed in the magnetic field in the air-gap, does not touch the pole pieces—or the core—but is connected mechanically to the center of the diaphragm by means of the flexible discs 3 and the steel rod 9.

When an alternating current is sent through the winding, 8, currents are induced in the copper tube. The winding and the copper tube really constitute the primary and secondary, respectively, of a transformer in which the primary is of many turns, and the secondary—in this case the tube—is of one turn of low resistance and short circuited on itself. In consequence, the currents induced in the tube are of very great strength. When the current in the tube flows in one direction, the action of the magnetic field in the gap is to cause the tube to move in the direction of its axis, and this motion is imparted to the diaphragm by means of the discs and the rod. Since the current in the tube alternates, the tube is moved first one way and then the other. This vibratory motion is imparted to the diaphragm and finally to the water particles, thus setting up sound waves in the water. An application of any of the hand rules for motor action will determine the direction of the force which is exerted on the copper tube at any instant.

The magnetism in the gap opposite the north pole of the direct-current field magnet passes through the copper tube in one direction, and in the region opposite the south pole passes through the tube in the reverse direction. In order that the forces exerted upon the upper and lower parts of the tube shall both be effective in moving the tube one way or the other at any instant, it is necessary that the induced currents in the two parts of the tube shall flow in opposite directions. This is accomplished by reversing the winding in one-half of the coil 8 as shown in the figure.

Oscillator Sending.—When the oscillator is in use the field magnet must be excited continuously by a direct current having a strength of about seven and one-half amperes. The alternating current, which is sent into the coil 8 to induce currents in the copper tube, usually has a strength of 11 amperes at a potential difference of 180 volts, and a frequency of 540 cycles per second.

With the apparatus as developed at present, the average signaling distance is from five to ten miles, although distances as great as 30 miles have been recorded.

Oscillator Receiving.—To arrange the oscillator for receiving it is only necessary to cut off the alternating-current supply and substitute one or more telephone receivers. The field must be excited with direct current as before.

Sound waves in the water move the diaphragm in and out; this motion is transmitted to the copper tube causing it to move back and forth in the strong magnetic field, thereby generating electromotive forces which send currents first one way and then the other around the tube. These currents induce, in the coil 8, electromotive forces which drive currents through the telephone receivers, thus reproducing in the air the sound waves which the oscillator receives from the water. The oscillator can be used for receiving signals from the submarine bell or from other oscillators.

Location of Oscillators.—Two oscillators are required, one on each side of the ship near the bow and in a position similar to that of the receiving tanks and microphones described in connection with the submarine bell. This location of the oscillator makes it possible to send signals from either side of the ship and to determine the range and direction of incoming signals exactly as with the tanks and microphones. Each oscillator is mounted below the water line, in a hole cut in the side of the vessel, the face of the oscillator being substituted for the skin of the ship. For signaling from shore, oscillators may be mounted on submerged tripods.

Accessories.—The accessory apparatus provided with the oscillator consists of a motor generator and a switchboard. The motor generator converts the direct current of the ship circuits into alternating current for use in sending. The switchboard is provided with a voltmeter, ammeter, frequency meter, rheostats, switches, sending key and telephone receivers. By means of the switches the operator is enabled to change quickly from sending to receiving and from one oscillator to the other.

The ordinary Morse code is used for signaling and speeds of 20 words per minute are not uncommon.

CHAPTER XIX.

ELECTRIC HEATERS.

Electric heaters are used to some extent on board naval vessels for cooking and for heating living spaces.

The underlying principle is the heating effect of a current flowing through a resistance.

The resistance units are wound for the full-line voltage of the ship. A great many different types of resistance units are used, from cast-iron grids to very fine resistance wire.

Heaters are classified in accordance with the watts required to operate them, and also in accordance with the number of ways in which the units may be electrically connected, as "Single-heat," "2-heat," "3-heat."

Single-Heat Type.—In this type the various resistance units are connected permanently in series (or in any series-parallel combination). The heater is placed in operation by closing a switch.

Two-Heat Type.—In this type the heat units are permanently connected in two groups, as shown in Fig. 258. Closing the double-pole switch connects R_1 in circuit, giving "low heat." Then the single-pole switch may be closed, connecting R_2 in parallel with R_1, giving "high heat." If E is the supply voltage, then the low heat is $\frac{E^2}{R^1}$ joules per second and the high heat is $\left(\frac{R_1+R_2}{R_1R_2}\right)E^2$ joules per second. If R_1 equals R_2, as is usual, the high heat is double the low heat.

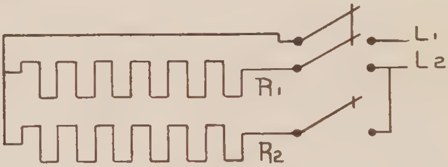

FIG. 258.—Two-Heat Type.

Drum-type controllers are sometimes used in place of the switches.

Three-Heat Type.—In this type the heating elements are connected as shown in Fig. 259. When the controller is on "low," R_1 and R_2 are in series.

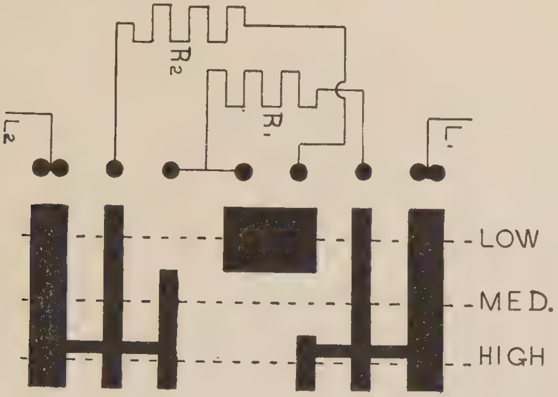

FIG. 259.—Three-Heat Type.

Then, if E is the supply voltage, the low heat is $\frac{E^2}{R_1+R_2}$ joules per second. When the controller is on "Medium," R_1 is across the line and R_2 is cut out. Medium heat is, therefore, $\frac{E^2}{R^1}$ joules per second. When the controller is on "high," R_1 and R_2 are in parallel. High heat is, therefore, $\left(\frac{R_1+R_2}{R_1R_2}\right)E^2$ joules per second. If R_1 equals R_2, low heat is $\frac{E^2}{2R}$, medium is $\frac{E^2}{R}$, and high is $\frac{2E^2}{R}$.

Simple switches are sometimes used in place of the drum controller.

Radiant Type.—Usually the heat units are buried in the insulating material or, in the cast-grid type, operated at a temperature below red heat. Broilers for galley use, and sometimes heaters in officers' quarters, are made of bare wire, operated at a bright red heat. These are known as "radiant-heat type."

CHAPTER XX.

ELECTRIC SHIP PROPULSION

Electric ship propulsion, or electric drive as it is usually called, is not an exactly descriptive term. The function of the electric power being simply to form a speed-reduction coupling between the main engines and the propeller shaft, the system is better described by the term "electric reduction gear" or "electric transmission."

Reasons for Adopting Electric Drive.—The general principles that govern the design of propelling machinery for battleships and battle cruisers are as follows:

1. For a given weight the machinery must develop the greatest possible power.
2. The machinery must be as economical as possible.
3. The ship must have two speeds at which the machinery is efficient—a fast speed for battle and a relatively slow speed for cruising. It is also of advantage to have machinery capable of considerable excess over designed full power for short intervals in emergencies.
4. Small changes in speed must be possible and positive to enable the vessel to cruise in formation.
5. The machinery must have strong backing power to insure safety in maneuvering in formation.
6. The machinery must, of course, be reliable and not delicate.

To secure the greatest possible power from machinery of a given weight requires high speeds, and the steam turbine is an efficient high-speed engine. The propeller is, however, efficient at low speeds only; so, to secure the maximum efficiency from both turbine and propeller, it is necessary to couple them together through a speed reduction gear. To meet this necessity, two coupling systems are being tried in the Navy—the mechanical reduction gear, usually known as the geared turbine system, and the electric drive.

Electric Drive and Mechanical Reduction Gear Compared.—Neither of these systems has been in use long enough to reach anything like the refinement that future development will bring, but there is much experimental data available which indicates that the relative advantages of the two systems are as follows:

1. Owing to difficulties in construction of pinions the mechanical gear cannot give as great a speed reduction as electric transmission.

2. The more power delivered the greater the difficulty in constructing mechanical gear, while a large induction motor is relatively easier to build than a small one.

3. The electric reduction gear is easily constructed to give two propeller speeds with the turbine turning at its most efficient speed, while the mechanical system gives but one speed reduction for a given turbine speed.

4. With electric drive full power is available for backing by a simple shift of electrical connections, while the mechanical gear is not reversible and backing turbines must be used, and these cannot be given as much power as the ahead turbines without prohibitive increase in weight.

5. Efficiencies are: mechanical gear, about 98 per cent; electric drive, 92 per cent.

6. The pinions and their equipment are lighter than the electrical plant for a given power, and on small ships the entire installation is lighter if mechanical gear is used, but as the size of the ship increases the difference becomes less.

7. The same is true in regard to the space occupied. With increase in size of the vessel the mechanical gear requires a greater increase in the number of turbine units and their piping than does the electric system, and in very high-powered vessels the advantage in weight and space probably lies with the electric drive.

8. The geared turbine is the less flexible coupling and does not absorb shocks from propeller racing with as little strain as does the electric drive.

9. The electric drive is more flexible in its arrangement. Geared turbines must be located close to the shafts they drive while in the electric engine room the alternators with the turbines and condensers may be located anywhere, thus saving much otherwise wasted space.

From the above it may be seen that, at the present stage of development, the electric drive is the better for battleships and battle cruisers because it is the better suited to high powers, gives greater backing power, and provides for the two efficient speeds which are of such great advantage to capital ships. For destroyers and light scout cruisers, where the power developed is not large and maneuvering qualities are properly sacrificed to getting the greatest power from the least machinery weight, the mechanical gear appears to be the better. While for types of vessels intermediate between the two cases cited above, the size of the ship and the service for which it is intended determine which system offers the most advantages.

General Principles of Electric Reduction Gear.—In general, the type of equipment adopted by the Navy consists of one or more alternators driven by high-speed condensing turbines, these units being designed for the speed which will give the best economy in steam consumption and weight. The

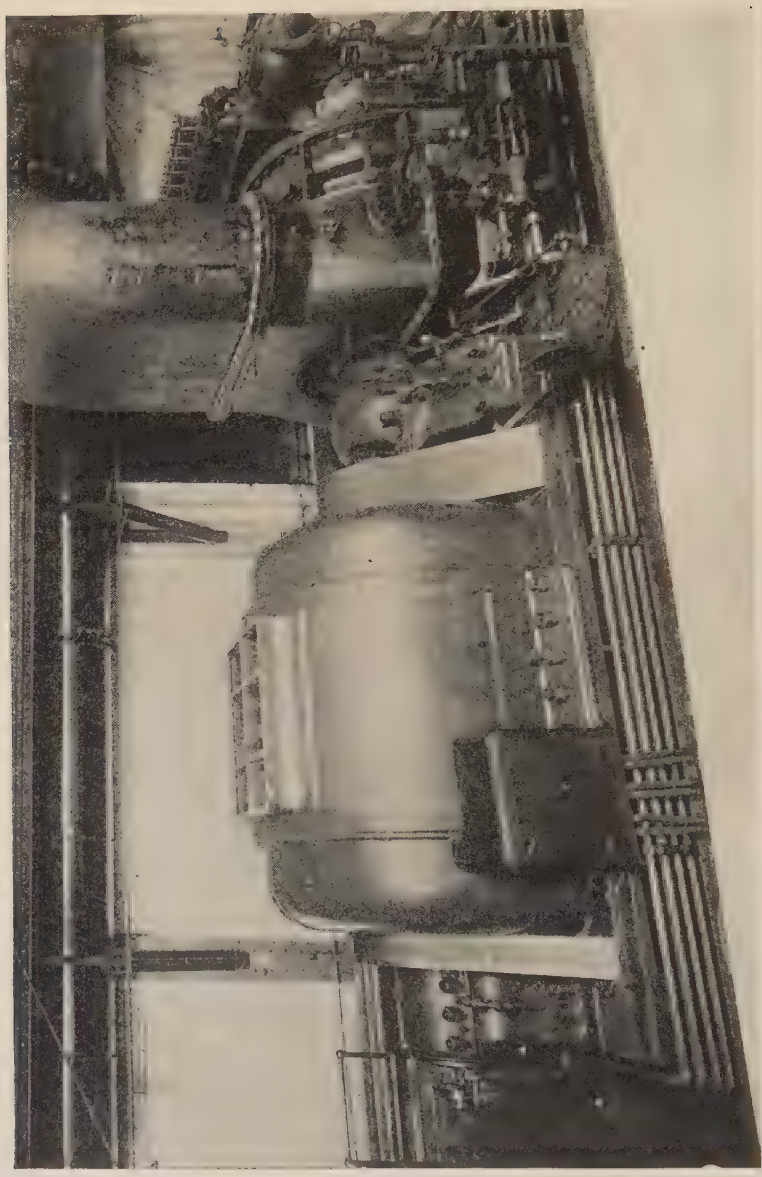

FIG. 260.—Alternator, U. S. S. *Jupiter.*

generating units are connected to induction motors which drive the propeller shafts. The electrical connections between alternators and motors are arranged to provide means for reversing the motors. Two speeds are provided for by winding the field of each motor so that two distinct pole groups may be formed. For example, a 2-pole alternator driving a 36/24-pole motor will give a speed reduction of about 18 to 1, or 12 to 1, depending on whether the 36-pole or 24-pole connection is in use. The two ship speeds obtainable with the designed full speed of the alternator are referred to as "the normal full speed" and "the normal slow speed." Slight changes from normal speeds are made by changing the speed of the turbines. The motor rotors are designed to produce the large torque demanded in starting the ship from rest or reversing its direction through the water; two distinct types of rotor—phase wound on the *Jupiter* and double squirrel cage on the *New Mexico*—have been adopted in order that the best points of each may be determined in actual service.

ELECTRIC REDUCTION GEAR, U. S. S. JUPITER.

The *Jupiter's* electric drive was installed with the idea of trying out the principles of the system and not because electric drive is particularly suited to this type of vessel. The *Jupiter* is a 20,000-ton, 14-knot fleet collier and, like other vessels of its class, needs but one efficient speed—the cruising speed of the fleet. Consequently the reduction gear is designed for but one normal speed instead of the two that are provided for in battleship installations.

General.—The propelling machinery consists of one 9-stage Curtis turbine direct connected to one 2-pole, 5450 K. V. A., 2300-volt alternator. The alternator supplies current to two 36-pole, 2750-horsepower, phase-wound induction motors in parallel, each motor direct connected to one propeller shaft. The arrangement provides a speed reduction (not considering the slip) of 18 to 1, so that when the alternator is operating at 2200 R. P. M. the motors and propellers have a speed of about 122 R. P. M. A water-cooled rheostat is provided that is introduced into the motor circuits to give the necessary torque for starting and reversing. With the resistance cut in the slip is increased and the normal speed of the motor reduced, it is only used in starting and reversing and is cut out at other times.

The Alternator.—This is of the revolving field, 2-pole type, the rotor (Fig. 261) having a distributed winding of copper strips. The exciting current is taken through two slip rings on the rotor shaft from one of the ship's 125-volt generators. The field resistance is about .39 ohm and the current through it is regulated by varying the voltage of the exciting generator by means of a rheostat in its field. The exciting current is normally about 250 amperes.

The Alternator Stator or Armature (Fig. 262) is bar wound, Y-connected, each phase consisting of two parallel circuits. The resistance per phase is about .003 ohm and the inductance of the armature is sufficiently high to prevent excessive current flowing should the leads be inadvertently short circuited. The alternator is totally enclosed, and the rotor has fans at each end which take air in at the bottom of the casing and blow it out through

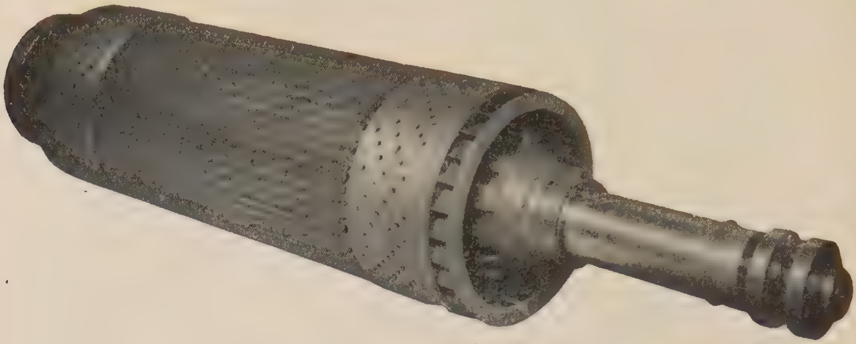

FIG. 261.—Revolving Field of Alternator.

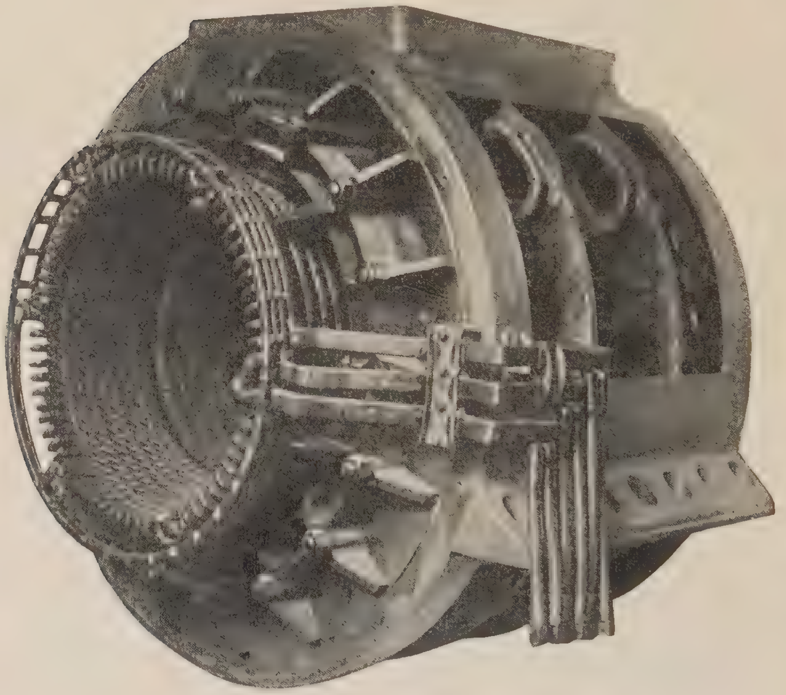

FIG. 262.—Alternator Stator.

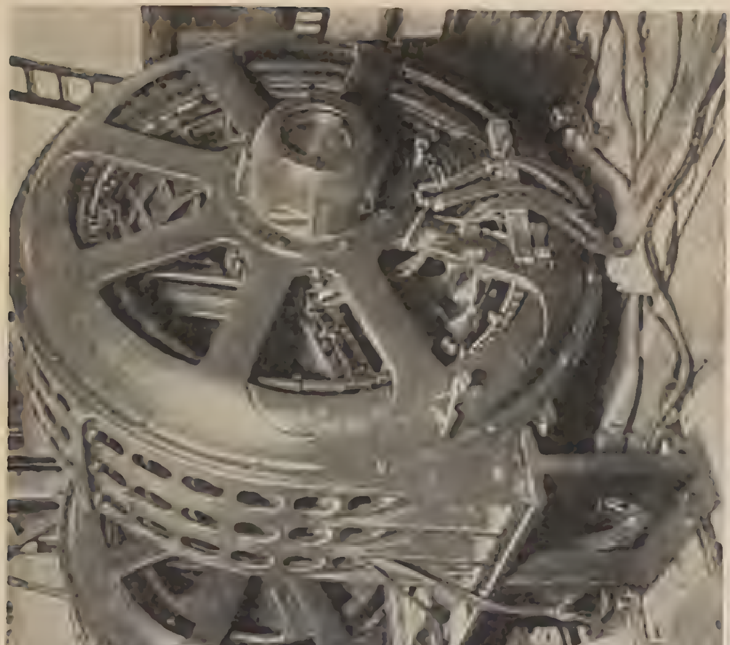

FIG. 263.—Main Motors, U. S. S. *Jupiter*.

the air-gaps and slots in the stator to a duct; this duct leads to the suction of the forced draft blowers, so the heat generated by the iron and copper losses of the alternator is passed into the furnaces.

The Motors.—Fig. 263 shows the *Jupiter's* two motors set up for shop tests. Each motor is installed on the ship in a watertight pit so that partial flooding of the engine room can do no harm.

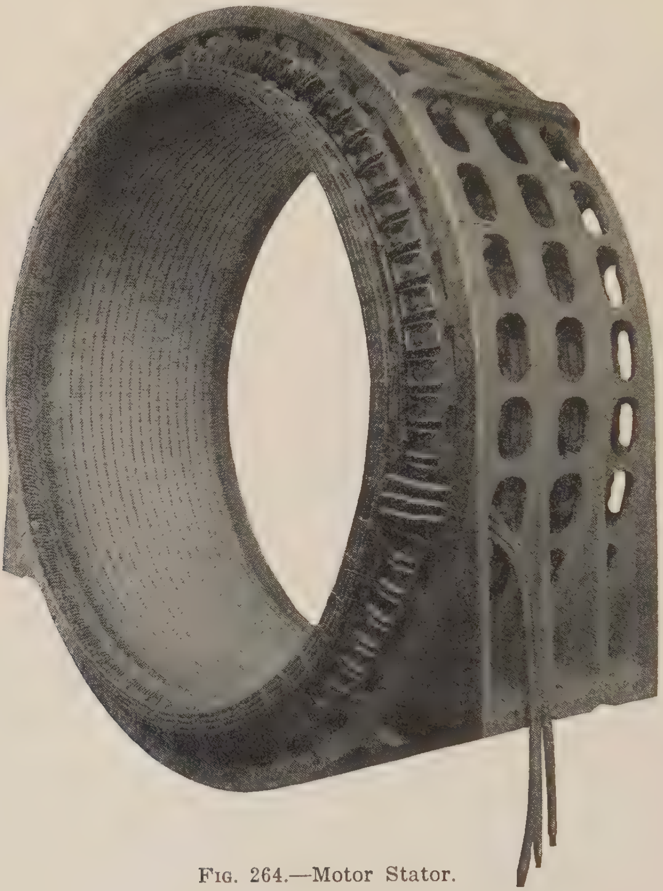

FIG. 264.—Motor Stator.

The motor stators (Fig. 264) have cast-steel frames with laminated steel cores, wire wound. The winding is Y-connected, each phase consisting of 12 parallel circuits. The stator of each motor is wound for 36 poles, thus giving a speed reduction, in connection with the 2-pole alternator, of very nearly 18 to 1, the slip being practically zero at light loads and about 1.5 per cent at full load.

The motor rotors (Fig. 265) are of the usual type, bar wound, Y-connected, four parallel circuits per phase. Current from the three slip rings of each motor is led to one of the two water-cooled rheostats. For normal speed these rheostats are cut out by means of a slider on the shaft of each motor. In its closed position the slider connects the slip rings together through practically no resistance, thus short circuiting the rotor winding. The slider is a switch mounted on and revolving with the shaft, which makes or breaks contact by sliding along the shaft. It consists of a brass contact on the inside of each slip ring and corresponding segments on the slider, made of interleaved brass strips which are compressed under the solid contacts on the rings as the slider is moved along on the shaft to its closed position. Secondary carbon-to-brass contacts are provided to take the spark at break as do the secondary contacts in the ordinary circuit breaker. The slider of each motor is operated by a "short-circuiting lever," the two levers being connected together so that movement of one operates both.

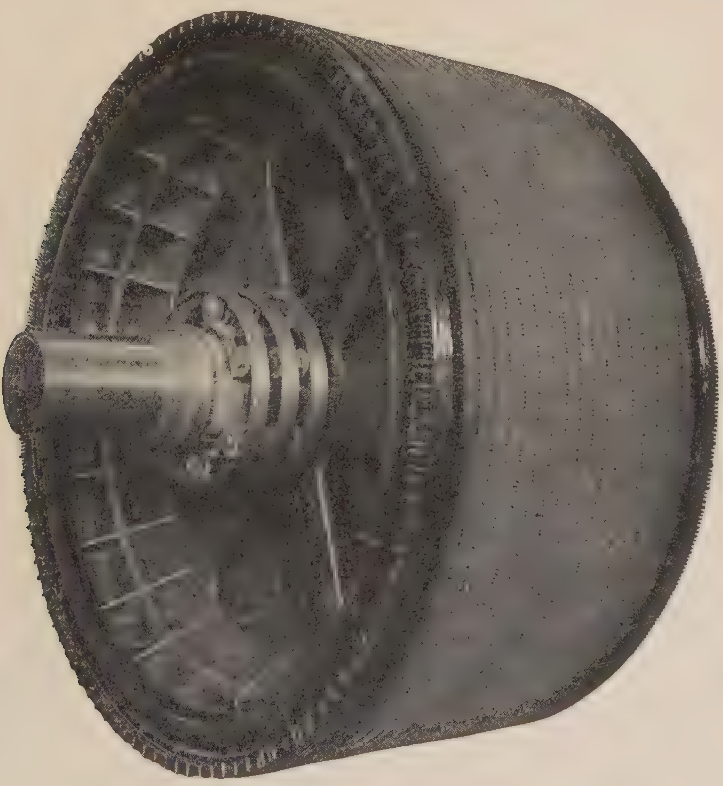

FIG. 265.—Motor Rotor.

The Rheostats.—There are two water-cooled rheostats, one for each motor. Each rheostat embodies three resistance units, one for each phase. Each unit is made up of a number of spiral coils of uninsulated calorite ribbon, connected in series as indicated in Fig. 266, the connections between coils being alternately at the center and at the edge to make the resistance non-inductive. The lead from one phase of the rotor is connected to the top coil of the corresponding resistance unit, and the bottom coils are joined by a common conductor, forming a Y-connection. The coils are mounted in the three large porcelain cylinders shown in Fig. 266. The small cylinders above them serve as connections to the upper water pipe. Sea water from the main circulating pump is forced through the lower pipe, up through the cylinders, and out through the upper pipe, carrying away the heat generated in the resistances. The energy absorbed by the rheostats is thus a dead loss, and it is to be expected that the efficiency of the reduction gear will be low with the rheostats in use. Points to be noted in connection with this type

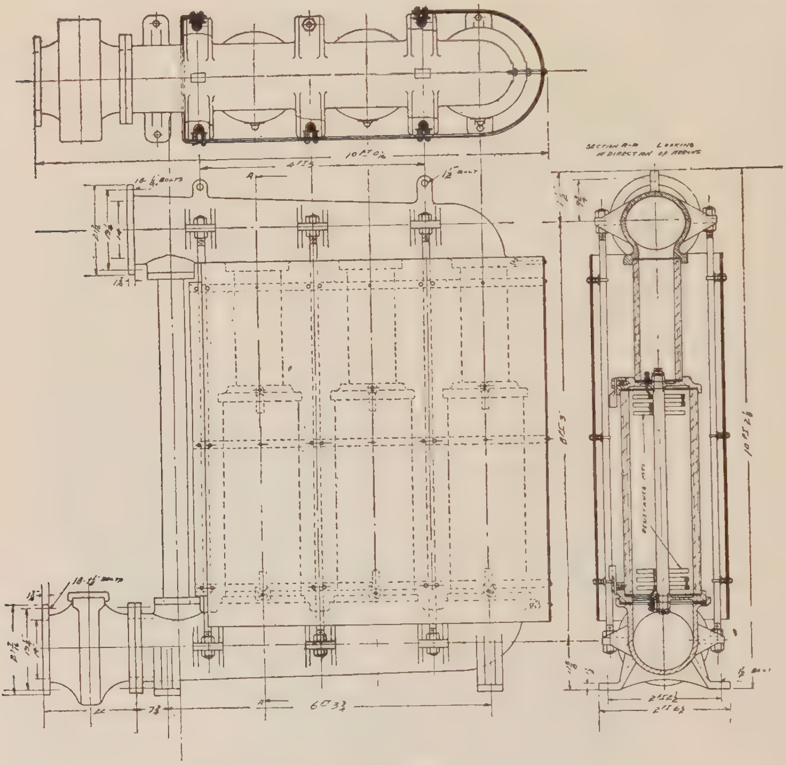

FIG. 266.—Water-Cooled Rheostat.

of rheostat are that the resistance is not adjustable, being either all in or all out; and the resistance units are not insulated from one another, having a common circuit through the circulating water; or, expressed in another way, the water is in parallel with the resistance units and serves to reduce the resistance to the desired amount.

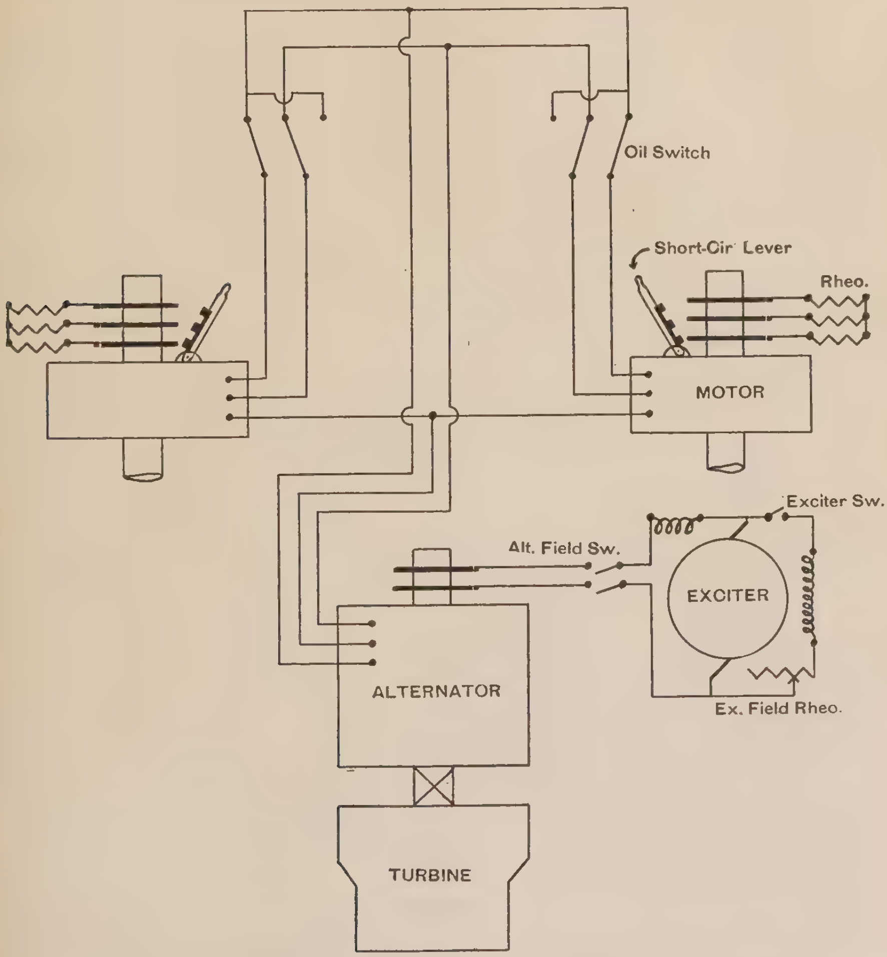
Oil Switch
Short-Cir Lever
Rheo.
MOTOR
Exciter Sw.
Alt. Field Sw.
EXCITER
ALTERNATOR
Ex. Field Rheo.
TURBINE

FIG. 267.—Elementary Diagram of Power Leads, U. S. S. *Jupiter*.

Electrical Connections.—Fig. 267 is an elementary diagram of the power leads in the *Jupiter's* engine room. The exciting current is taken from any one of the three 35 kw. ship's generators, the generator selected as the exciter being disconnected from its panel on the dynamo-room switchboard and connected to the main switchboard in the engine room through the circuit shown in Fig. 267. The intensity of the exciting current is varied at the main switchboard by the exciter field rheostat and the exciter switch is used to take power off the motors, the opening of this switch which carries very little current, being sufficient to take power off the entire system. The series field of the exciter is never disconnected because the machine will unbuild as soon as the shunt field is interrupted.

The secondary leads from the alternator are arranged so as to make the two motors as independent as possible. One phase leads direct to the two motors. The other two phases lead to the oil switches which have three positions—open, closed ahead and closed astern. The ahead and astern switches are actually separate but mechanically interlocked so that both cannot be closed at the same time.

It is evident from the diagram that one motor may be stopped, going ahead, or going astern, regardless of what the other is doing; but the interlock between the short-circuiting levers enforces the condition that, if both motors are moving, they must be turning at the same speed.

The main switchboard is located just forward of the motors so that the short-circuiting levers may be handled conveniently by the switchboard attendant. On this board are mounted all the switches shown in Fig. 267, the exciter field rheostat, the necessary voltmeters, ammeters, and wattmeters, and the usual steam gauges and revolution indicators, so that the whole plant may be controlled by one man from this station.

To prevent the making of wrong connections the following interlocks are provided:

1. The short-circuiting levers are locked together as previously explained.
2. The short-circuiting levers are locked by solenoids in the alternator field circuit so the rotor resistance cannot be cut out while power is on the motors, but may be cut in under any conditions.
3. The oil switches are mechanically locked to the short-circuiting levers in such a way that no open switches can be closed when the resistance is cut out, but those that are closed can be opened under any conditions.
4. The ahead and astern oil switches are mechanically interlocked so that only one for each motor may be closed at a time.

The general idea of the interlocks is to permit stopping the propellers by opening the oil switches whether resistance is in or out, but to prevent starting the propellers either ahead or astern unless resistance is in. Furthermore, the interlocks prevent cutting out the rotor resistance when the circuits are energized, but permit cutting in the resistance when power is on the motors.

Change of speed is provided for by adjustment of the governor of the main turbine. The governor is of the spring-loaded centrifugal type, the centrifugal motion of the weights operating a small pilot valve which admits oil, supplied by a pump under 75 pounds pressure, to a hydraulic relay. The relay operates the eight control valves that admit steam to the turbine and is fitted with a follow-up device which operates to close the pilot valve. Thus, if the turbine momentarily speeds up, the governor arm lengthens; this opens the pilot valve, admitting oil to the relay cylinder and moving the relay piston so as to close one or more valves. This slows the turbine and at the same time the follow-up device closes the pilot valve, which remains closed until a further movement of the governor takes place. The connection between the governor arm and the pilot valve is adjustable in length, and the adjustment is made by means of a control wheel mounted on a stand in front of the main switchboard. Thus the speed of the turbine, and consequently that of the motors, is absolutely under the control of the switchboard operator. The constancy of speed is of great advantage in a rough sea, when the propellers have no tendency to race when they pitch out of water. There is, however, one disadvantage in that when the rudder goes over, one propeller cannot slow down as it does with free running engines, and the motor driving this propeller will carry a heavy overload at high speeds. Battleship installations, where there is at least one alternator running for each shaft when full power is in use, have an interlock between the rudder and the turbine governors so that when the rudder goes over the proper propeller will slow down.

The *Jupiter's* machinery was designed for operation as described below. Changes have been made since the ship was commissioned in order to simplify the various steps but the original methods better illustrate the principles and are, therefore, given here.

1. **Preparing to Get Underway.**—Warm up turbine and start auxiliaries in the usual manner. Rotor resistance is cut in and alternator field is excited.

2. **Getting Underway.**—Simply close ahead or astern switches as required by signals from the bridge.

3. **To Back, Propellers Going Ahead.**—Throw oil switches from ahead to astern.

4. **To Increase or Decrease Speed.**—Move governor control wheel.

5. **To Stop.**—Open oil switches.

These five operations are all performed with the rotor resistance in, this being the normal condition when getting underway or coming to anchor, or when maneuvering. The full speed obtainable with resistance in is about nine knots.

6. **To Cut Out Resistance.**—With the proper oil switches closed and the ship moving through the water, open exciter switch, move control wheel to

"slow," move short-circuiting levers to "resistance out," close exciter switch, bring turbine up to speed desired.

When running with resistance out, minor changes in speed are made by changing the setting of the turbine governor. The motors may be stopped at any time by simply opening the oil switches; the resistance is then cut in so as to be ready for maneuvering. As a matter of fact the *Jupiter* can be maneuvered at slow speeds without using the rotor resistance, and it is only when the motors are reversed with the ship making way through the water at about eight knots that the load exceeds the pulling out torque in this condition.

"Electric propulsion" is being installed on new battleships and cruisers, and a number of new features and improvements in the design will doubtless be made.

Detailed descriptions of these installations, however, are not now available for publication.

CHAPTER XXI.

THE SPERRY GYROSCOPIC COMPASS[*]

Precession.—Fig. 268 represents a wheel mounted on an axis, X, and rotating in such a direction that the bottom is moving up from the plane of the paper. According to a fundamental principle of physics, the wheel tends to remain in its state of uniform circular motion. If the axis, X, is inclined by a couple, T (Fig. 268a), reaching the position shown by dotted lines in one-half revolution of the wheel, a particle, A, will follow the path AB. It is displaced to the left. By virtue of its tendency to remain in a state of uniform circular motion, it resists this displacement, the resistance being a force acting to the right. In Fig. 268b, CD represents the path of a particle starting at the top and moving down with the back of the wheel. This is displaced to the right, and accordingly exerts a force to the left. Therefore, all particles in the front of the wheel (by "front" is meant the half of the wheel above the plane of the paper) exert a force to the right, and all particles in the back of the wheel exert a force to the left. These forces are represented by R and L in Fig. 268c. They form a couple tending to turn the left end of the axis X *up* from the plane of the paper. If free, therefore, the left end of X will move up from the plane of the paper, rotating about the vertical axis of the wheel. If the torque T is applied continuously downward at the left end of the axis X, this rotation will continue as long as the torque acts. If the torque is applied continuously downward *in the plane of the paper,* as the axis X rotates, the component of the

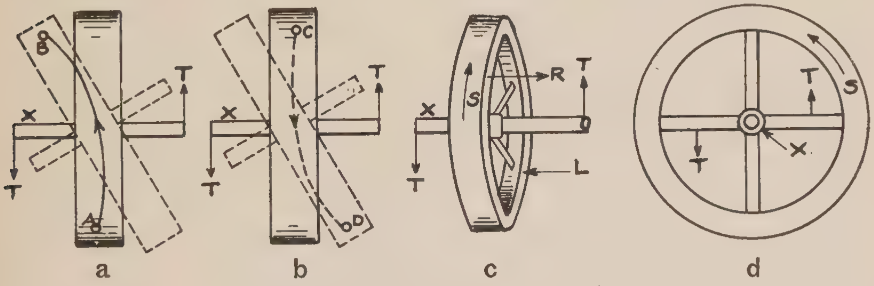

Fig. 268.—The Forces Causing Precession.

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[*] The following notes are intended to explain gyroscopic action only in so far as it applies to the Sperry compass, and the description of the compass is limited to the details necessary for an understanding of the electric features.

torque tending to incline the axis decreases as the cosine of the angle swept out by the axis. When the axis has rotated through 90°, the wheel is revolving in the plane of the paper, and the component of the torque tending to incline the axis has reduced to zero, and no force is exerted due to displacement of the particles.

(The amount of inclination shown in Fig. 268a and 268b are greatly exaggerated.)

This movement of the axis of spin is called **precession.**

The Law of Precession, illustrated above, is: **The axis of spin of a gyroscope tends to swing around so as to set the wheel parallel to an impressed torque, and in such a relation that the direction of rotation of the wheel is the same as the direction of the impressed torque.**

The angular velocity of precession is proportional to the impressed torque. The energy that would be expended by the impressed torque in tilting the axis, if the wheel were not revolving, is entirely absorbed by the precession. For example, if a weight were hung on one end of the axis X of the wheel represented in Fig. 268, it would not pull the axis down, but would cause continuous precession about a vertical axis. If the weight were increased, the speed of precession would increase correspondingly. This assumes that the precession is not resisted. If it is resisted by friction or some other force, this force may be considered as an impressed torque which will create a precession of the axis X, causing it to tilt. Thus if a weight were hung on the left end of the axis X of Fig. 268, and precession of the wheel were resisted by friction, the wheel would precess as shown and also tilt as indicated by the dotted lines in Figs. 268a and 268b, the angular velocity of the inclination being proportional to the force of the friction.

Degrees of Freedom.—A wheel mounted as shown in Fig. 269 is said to possess three degrees of freedom.

1st degree.—It can rotate about axis X.
2d degree.—It can rotate about axis Y.
3d degree.—It can rotate about axis Z.

The Gyro Compass on Land.—The Sperry compass is essentially a gyroscope with three degrees of freedom. A pendulum (called the **bail**) is attached to the compass in such a way that it hangs vertically only when the axis of spin of the wheel is horizontal. The action is most easily understood by the use of the diagrams like Fig. 270, in which the gyroscope is represented without its supporting rings. Three principles should be applied when investigating the actions illustrated by the diagrams that follow.

(1) The axis of spin tends to remain parallel to itself in space. (2) If this results in the axis leaving the horizontal plane, the pendulum will exert a torque *tending* to return it to the horizontal plane. (3) This torque will

cause precession. The direction of the precession may be determined by indicating the torque exerted by the pendulum and the rotation of the wheel by arrows; then the axis will precess until the arrows coincide in direction and in plane.

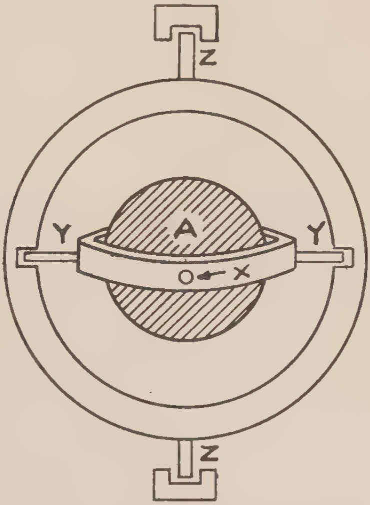


Fig. 269.—Gyroscope with Three Degrees of Freedom.

Fig. 270 represents the earth as seen from a point above the north pole. The outer circle represents the equator and the inner circle the parallel of 45° north latitude. The lines 1, 2, 3, 4, 5 represent successive positions of a meridian as the earth revolves.

Considering the compass at the equator, in position 1 it is shown with its axis in the east and west line and horizontal. In 2 the earth has revolved and the tendency of the axis to remain fixed in space has caused it to leave the horizontal. The bail then applies the torque T tending to pull the axis back to the horizontal position. This causes it to precess as shown at 3, the end of the axis N pointing to true north. The axis regains the horizontal, precession ceases, and thereafter N points always north and remains horizontal and parallel to itself in space. The axis thus acts as a compass needle.

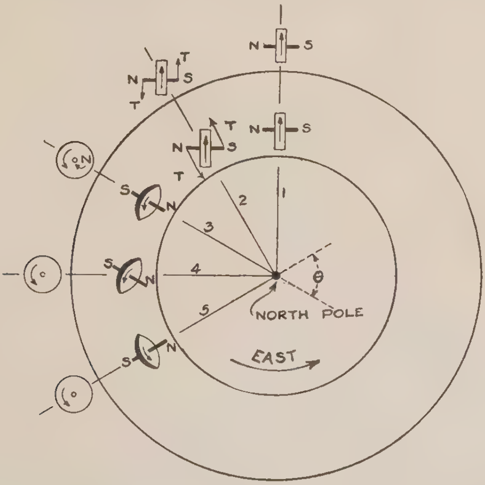


Fig. 270.—The Directive Effect of the Gyro Compass.

Considering the compass at 45° north latitude, the actions in positions 1 and 2 are the same as for the other compass, and it precesses to north. But the axis of spin, being horizontal, is inclined 45° to the axis of the earth, instead of being parallel to it as was the case with the compass on the equator. Now if the axis of this compass remains parallel to itself and horizontal it will not remain in the meridian, as shown by position 4. It is evidently necessary to produce a continuous counter-clockwise precession to make it hold the meridian, the rate of the precession being $\theta°$ in the time between position 3 and position 5. As explained on page 422, a weight on one end of the axis will cause continuous precession. The wheel is turning counter-clockwise when viewed from the end marked N. Reference to Fig. 268 will show that to produce counter-clockwise precession, a force must be exerted tending to pull N down (N corresponds to the end marked X in Fig. 268). Therefore, placing a small weight at N will cause the required continuous precession. This weight must be just sufficient to cause precession at a rate just equal to that at which the rotation of the earth would cause X to move away from the meridian, and must be in the opposite direction. Fig. 271 represents the earth as viewed from the plane of the equator, and the angle θ is the precession that must take place in 12 hours for the compass to remain horizontal and in the meridian. As indicated, θ is 0° at the equator, and increases with latitude; therefore, the weight must be increased as the latitude increases. Also, the precession south of the equator is in the opposite direction, so the weight must be shifted to the S end of the axis of spin when in south latitudes. In the actual compass this weight is applied by shifting the bearings of the bail so as to unbalance it slightly, making the north end heavy in north, and light in south latitudes. It must not be supposed that without this "latitude weight" the compass would deviate from the meridian. Without the weight it would settle in the meridian with the north end of its

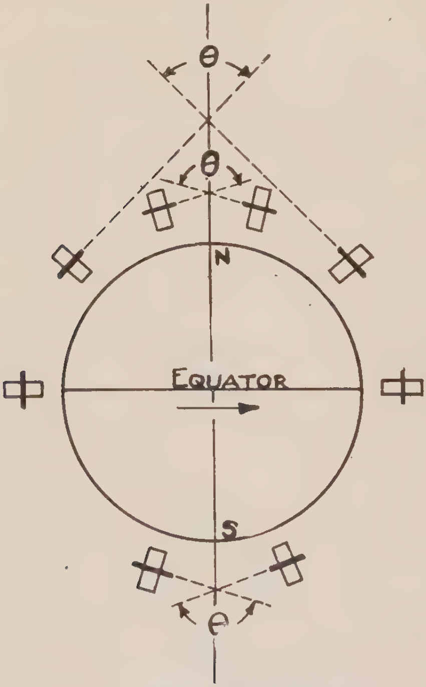


FIG. 271.—Continuous Precession of the Compass.

axis slightly elevated in north latitudes or slightly depressed for south latitudes, which would create the torque necessary for the constant precession. The only reason for shifting the bail bearings instead of allowing the axis to tilt up is that an inclination of this axis would result in a component of torque about the vertical axis of the compass whenever the speed of the wheel changed.

Elementary Idea of the Sperry Compass.—Fig. 272 is a diagrammatic sketch of the Sperry compass. The wheel A is spinning on the horizontal axis N (the axis of spin) in the airtight case B, which corresponds to the horizontal ring of the gyro in Fig. 269. The case is mounted in the vertical ring D upon bearings CC. Ring D is suspended by a flexible wire E, which corresponds to the bearing ZZ of Fig. 269. This much of the compass supplies the three degrees of freedom. The ring G is employed to carry the bail and the compass card, it being necessary to free the sensitive part of the compass from the disturbing effects of friction. The slightest movement of the sensitive element, as the combination of the wheel, case, and vertical ring is called, makes contact to an electric motor which causes a corresponding movement of ring G. This ring, therefore, follows the sensitive element like a shadow, from which it derives its name, **phantom.** The phantom is pivoted at the top on ball bearings, and the supporting wire E is attached to a cap on the hollow stem of the phantom. Thus the sensitive element twists the wire never more than a fraction of a degree. The bail is pivoted on bearings on the phantom, passes through slots in the ring D, and is attached to the casing at S.

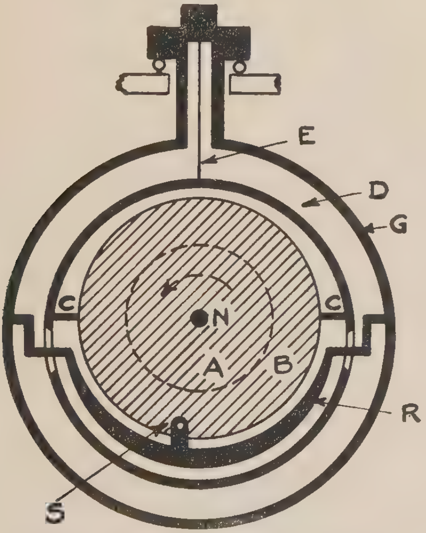


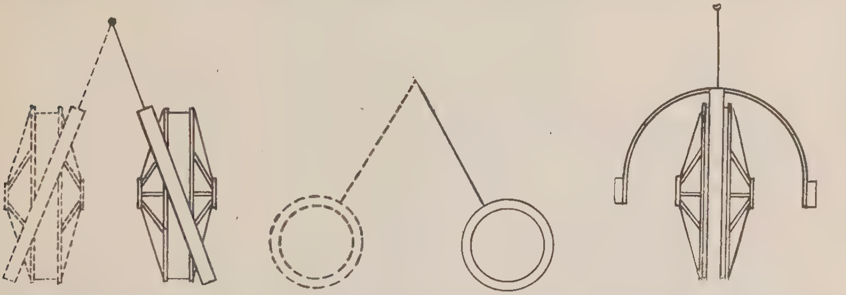
FIG. 272.—Diagrammatic Sketch of the Sperry Compass.

Damping.—In the discussion of the directive effect of the gyroscope, it was shown that precession is caused by torque exerted by the bail. It is therefore evident that the bail must be inclined from its normal vertical position before precession begins, because a pendulum exerts no torque when it is vertical. And the bail must be inclined all the time that precession is taking place, because its torque disappears as soon as it becomes vertical. Now suppose a compass started on the equator with the north end pointing east as shown in Fig. 270. The rotation of the earth lifts the north end of the axis of spin. This swings the pendulum out of the vertical and the resulting torque causes the precession. When the axis reaches the meridian the pendulum is still inclined, so the compass will go on precessing until the rotation of the earth, which is now acting to *raise* the *south* end of the axis of spin, restores the bail to the vertical position. If there were no friction, it would take as long to bring the axis of spin horizontal after crossing the meridian as it took to incline it before reaching the meridian. Consequently, it would swing as far to the west as it was to the east when the swing began. A swing of equal amplitude would then take place towards the east, and the oscillations would continue indefinitely. In the actual compass these oscillations are damped to some extent by friction; but friction is necessarily reduced to a minimum and it would take many hours for the compass to settle in the meridian. More rapid damping is necessary in a practical compass. Now, any means that would return the pendulum to the vertical at the instant it reaches the meridian would prevent oscillations. In the actual compass the eccentric connection S works on this principle. Referring to Fig. 272, it should be noted that S is slightly to the left of a vertical line through N (about ¼ inch in the actual compass). If N is raised, the bail tends not only to pull N downward, but also, by virtue of its eccentric position, to pull N to the left. This pull to the left causes precession in such a direction that N moves down. Thus the axis of spin reaches the meridian more nearly horizontal than it otherwise would, and swings beyond it only a short distance. The swing back is likewise damped and the compass soon settles on north. It should be noted that the compass is energized by the tilt of its axis, and the eccentric connection de-energizes it by reducing the tilt. The action is analogous to damping the oscillations of a pendulum by friction, the force of friction de-energizing the force causing the swing.

Latitude Correction.—As explained, the compass when not at the equator must be continually precessing in order to hold the meridian. The damping force is constantly opposing this precession so the compass does not settle exactly on the meridian, but in a plane where the damping force and the force of precession are in equilibrium. The damping force is constant, depending only on the eccentricity of the connection S in Fig. 272, but the force of precession varies with the latitude as illustrated in Fig. 270. Consequently, a "latitude correction" must be applied to the compass readings. In the actual compass the lubbers point is shifted to make this correction, so true courses are given by the compass card.

Correction for Speed of the Ship.—If a ship is heading east or west, its movement is added to or subtracted from that of the earth and has no effect on the compass. If moving north or south, its speed causes a deviation. Imagine the rotation of the earth stopped and the ship sailing on the meridian. Then, in passing from the equator to a pole, the axis of the compass, if pointing north, would be inclined through 90°. The resulting precession would cause the axis of spin to settle in an east and west line. Now the rotation of the earth is enormously great as compared to a ship's speed, consequently, the precession due to the earth's rotation is much greater than that due to the ship's speed. The latter causes a deviation depending upon (1) the speed of the ship, (2) the course, since only the north or south component of the ship's speed causes the deviation and (3) the latitude. This deviation is corrected in the compass by shifting the lubber's point, the correcting device consisting of a series of links and cams with two adjustments, one for latitude and the other for speed. The compass itself makes the adjustment for course.

Effects of Rolling and Pitching of the Ship.—Any oscillations of the ship are transmitted to the sensitive element through the friction of the bearings, and tend to cause the compass to swing as a pendulum. Fig. 273 represents the compass swinging in a north-south plane. The vertical ring tends to remain parallel to the supporting wire at all times, but the sensitive element is stabilized by the gyro and remains parallel to itself. A property of a thin pendulum bob, such as is formed by the vertical ring, is a tendency to set itself edgewise in the plane of the swing. In this case its tendency is to turn through 90° as shown in Fig. 273b, and this would cause a deviation of



a. The sensitive element swinging in an east-west plane.

b. The vertical ring tends to set its principal axis in the plane of the swing.

c. The tendency of the vertical ring to twist is suppressed by compensating weights.

FIG. 273.

the compass. A spherical pendulum bob has no tendency to twist as it swings, so the vertical ring of the Sperry compass is made spherical in so far as the

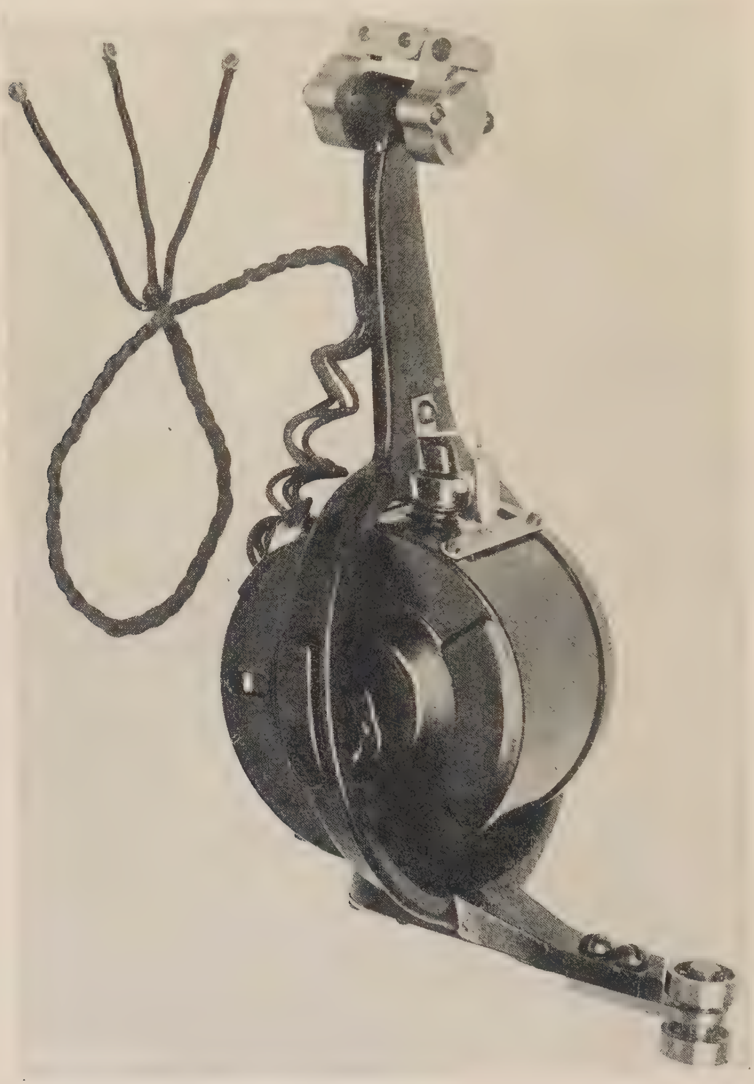


FIG. 274.—Floating Ballistic or Stabilizer.

distribution of weight is concerned by the addition of weighted arms as indicated in Fig. 273c. These are called **compensating weights.**

Referring to Fig. 272, imagine the whole compass to swing in a NE. to SW. plane (the observer is looking at the north end of the compass). The easterly (left) component of the swing causes S to move to the left of the vertical plane through N. The swing to north causes S to pull N up and to the right (see Fig. 273a; the bail has a tendency to follow the motions of

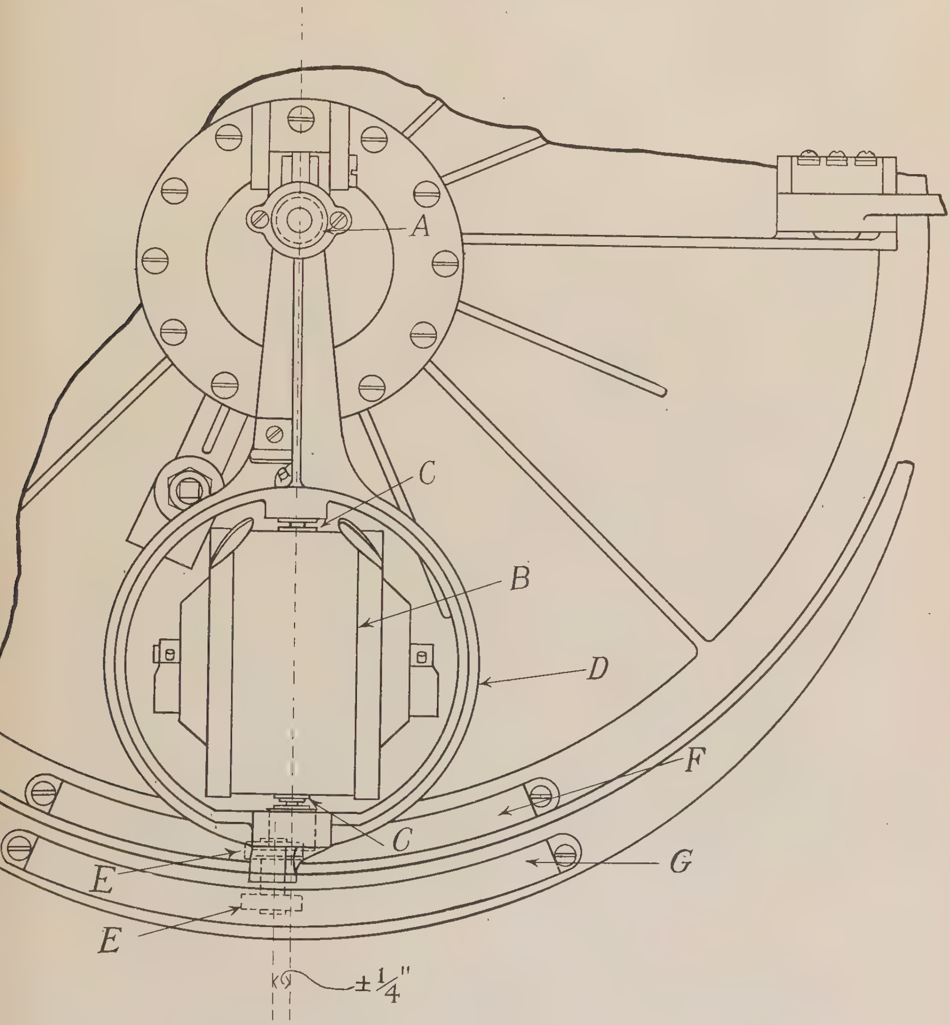


FIG. 275.—Mechanical Connections of Floating Ballistic.

the vertical ring). Having reached the extreme northeast end of the oscillation, the compass returns to the horizontal, the bail all the time tending to pull N up and to the right. After passing the horizontal, S moves to the right of the vertical line through N and thus tends to pull N down and to the right. Thus the oscillations tend to tilt the axis of spin alternately up and down, but always to the right, and will cause a deviation. A swing in a NW. to SE. plane would cause a torque tending to turn N to the left. It may be seen that if S always remained on one side of the vertical plane through N, the steady sidewise torque on N would become alternating like the vertical torque. In the actual compass the pivot of contact between bail and case is held fixed in relation to the vertical plane through N by means of an auxiliary gyroscope, which, together with its support, is called the **floating ballistic** or **stabilizer**. It is illustrated in Figs. 274 and 275. Referring to Fig. 275, the ballistic is pivoted in bearing A on the north end of the main gyro case, and is free to swing to left or right. The small gyro is contained in the case B, spins about an east-west axis, and is free to precess about the vertical bearings CC. Any tendency to move the ballistic to right or left is resisted by the stabilizer gyroscope, so the ballistic remains vertical when the compass swings. The rollers EE run in tracks (F attached to the wheel case, and G attached to the bail) and form the point of contact between case and bail, which is thus kept fixed with respect to the vertical plane through the axis of spin of the main gyro.

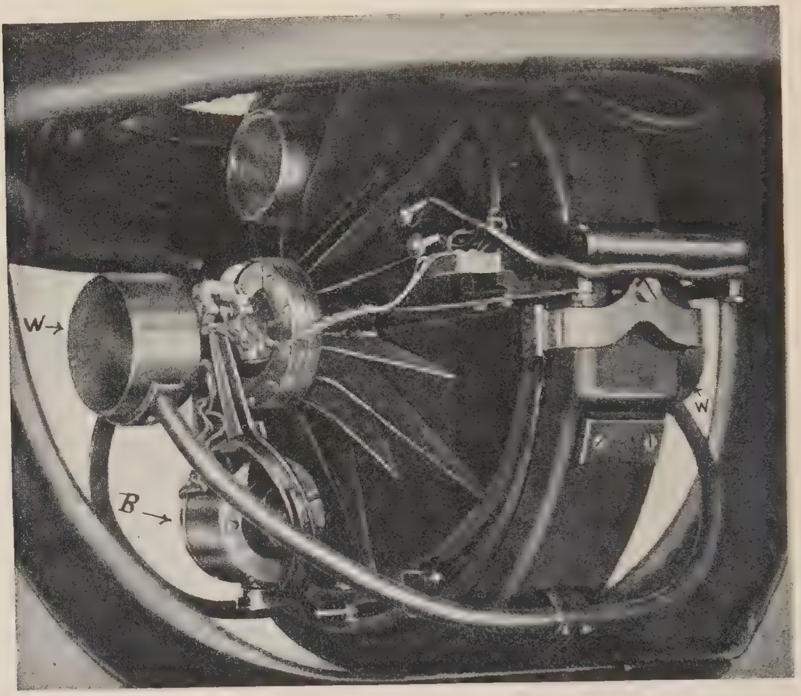


FIG. 276.—Master Compass, Showing Ballistic B and Compensating Weights WW.

Fig. 276 shows the actual appearance of the compensating weights W and the ballistic B. The arms of the compensating weights are secured to lugs on the vertical ring, these lugs passing through slots in the phantom.

Description of the Compass.—The gyro compass itself is called the **master compass.** It is located in a sheltered part of the ship and is not used directly for navigational purposes. Any number of dummy compasses, called **repeater compasses,** may be located in various parts of the ship. These are electrically connected to the master compass and indicate the bearing of the ship's keel from true north as registered by the master.

The Master Compass.—The general arrangement of the master compass is shown in Figs. 277 and 278. Fig. 277 is an elaboration of Fig. 272, but viewed from the south instead of the north end; the parts are lettered as in Fig. 272.

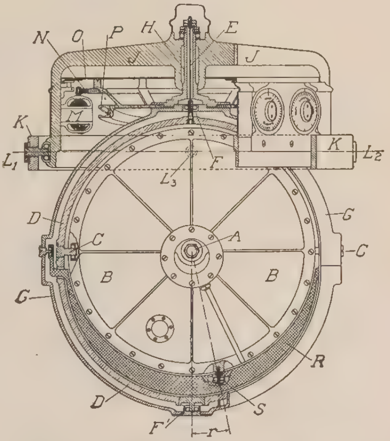


FIG. 277.—Master Compass. South Elevation (Ballistic and Compensating Weights Removed).

The gyroscope wheel is mounted to rotate on a horizontal shaft A within the casing B, which is pivoted on the horizontal axis C through its center of gravity and carried by the frame or vertical ring D.

The ring D is suspended by a torsionless strand E and guided by bearings F and F′ to allow a free oscillation of limited amount about its vertical axis within the frame or phantom G. The phantom G has a hollow stem H, to which the strand E is attached at its upper end, and the stem forms a journal for rotation in azimuth with respect to the supporting base frame J.

The frame J is mounted to swing in the binnacle by the usual Cardan suspension, consisting of the ring K and suitable bearings L1, L2, L3 and L4.

The frame J carries a "follow-up" motor M, called the **azimuth motor,** driving a gear N, forming a rigid part of the phantom G, whereby the latter is positively driven in azimuth to respond to any movement of ring D.

The ring D (which, with the wheel and casing, is termed the "element") is provided with electrical trolley contacts, *a, a,* which co-operate with stationary contacts *b, b′* and *b, b′* (see Fig. 280), the latter being mounted upon the phantom G to control the azimuth motor M, the electrical connections not being shown in these figures.

The power-driven phantom G is thus automatically controlled so as to respond instantly to all movements of the sensitive element, and, in fact, to all relative movement in azimuth between the ship and the gyro.

Forces are impressed upon the wheel case B by means of bail R acting through connection S, which is shown in Fig. 277 as a plain bearing, but which in practice is formed by two rollers on the lower end of floating ballistic T running in tracks W1 and W2. The floating ballistic then serves to stabilize this connection and hold it in a fixed position with respect to a vertical plane passing through the center of shaft A.

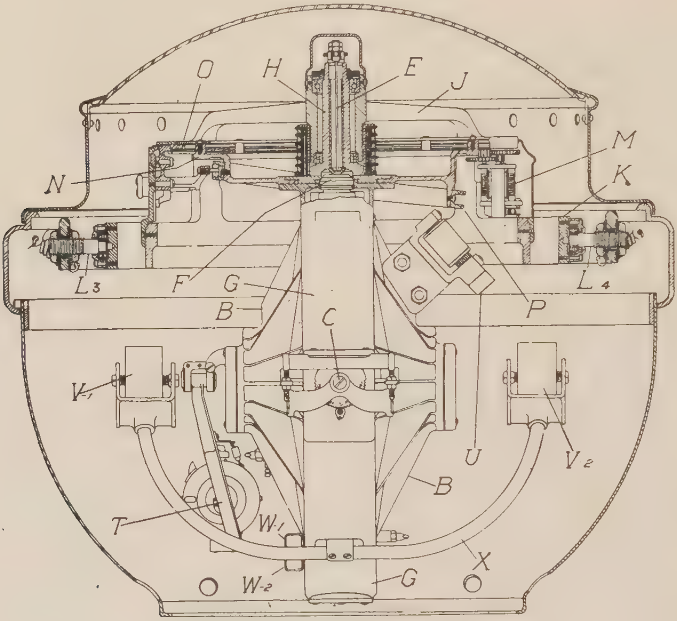


FIG. 278.—Master Compass, West Elevation.

Compensating weights V1, V2 are attached to the vertical ring D by means of arms X. These serve to give the correct distribution of mass of ring D and attached parts required to neutralize the effect of disturbing forces due to rolling and pitching of the ship.

Electrical Devices of the Sperry Compass.—The **gyro wheel** (Fig. 279) is the rotor of a three-phase squirrel-cage induction motor. The stator is attached to the case. It is Y-wound for 90 volts. To reduce windage, a high vacuum is maintained in the case. The normal speed of the wheel is 8600 R. P. M., which is reduced to about 7000 R. P. M. if the vacuum is lost.

The **stabilizer gyro** is similar in construction to the main gyro, but much smaller. The stator is delta-wound. It is supplied by the mains that lead to the main gyro, but the E. M. F. is stepped down to 10 volts by a transformer. The low voltage allows of a more rugged winding, and the interposition of the transformer protects the main gyro from derangement due to short circuits in the stabilizer circuits. The speed of the auxiliary gyro is from 7000 to 8500 R. P. M.

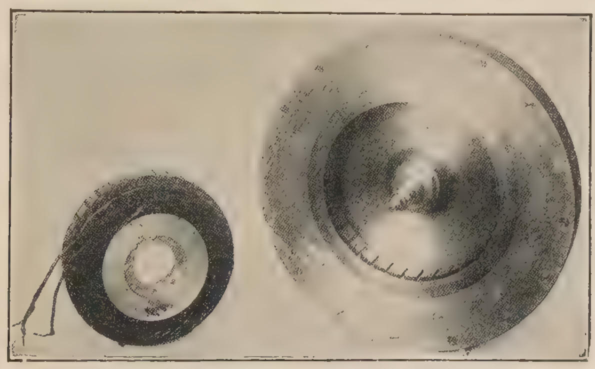


Fig. 279.—Main Gyro Wheel and Stator.

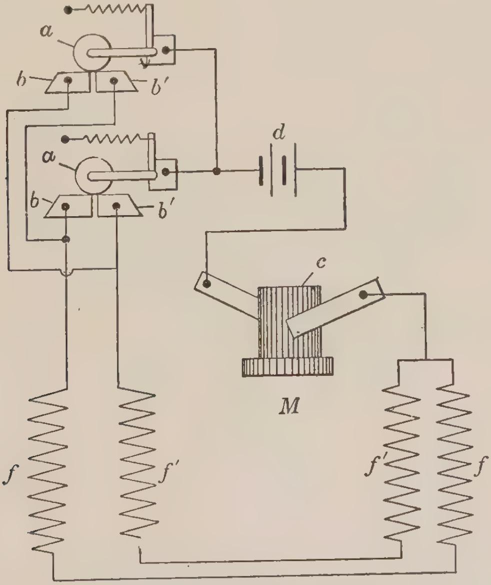


Fig. 280.—Diagram of Azimuth Motor Circuits.

The azimuth motor (M in Fig. 277) is controlled by relative movement of the ship and sensitive element in azimuth. The operation may be followed from the elementary diagram in Fig. 280. The trolley wheels *a* are mounted on opposite sides of the ring D (Fig. 281). The contacts *b*, *b′* (Fig. 280) are mounted on the phantom. The motor M is mounted on the binnacle and its shaft is geared to the phantom. If the sensitive element turns anti-clockwise, wheel *a* makes contact with block *b*. Current flows from the line (represented by battery *d*) through *a* to *b* through the fields *f*, *f* to the motor. The motor revolves, driving the phantom in the same direction as the sensitive element has moved. When the phantom catches up to the element, the wheel *a* leaves block *b* and motion ceases. If the element moves clockwise, wheel *a* makes contact with block *b′*, and current then flows to the motor through the fields *f′*, *f′* which are wound oppositely to fields *f*, *f*, thus reversing the motor. As actually constructed, the two blocks *bb′* of a pair are very close together, and the trolley wheel is always on one or the other. There-

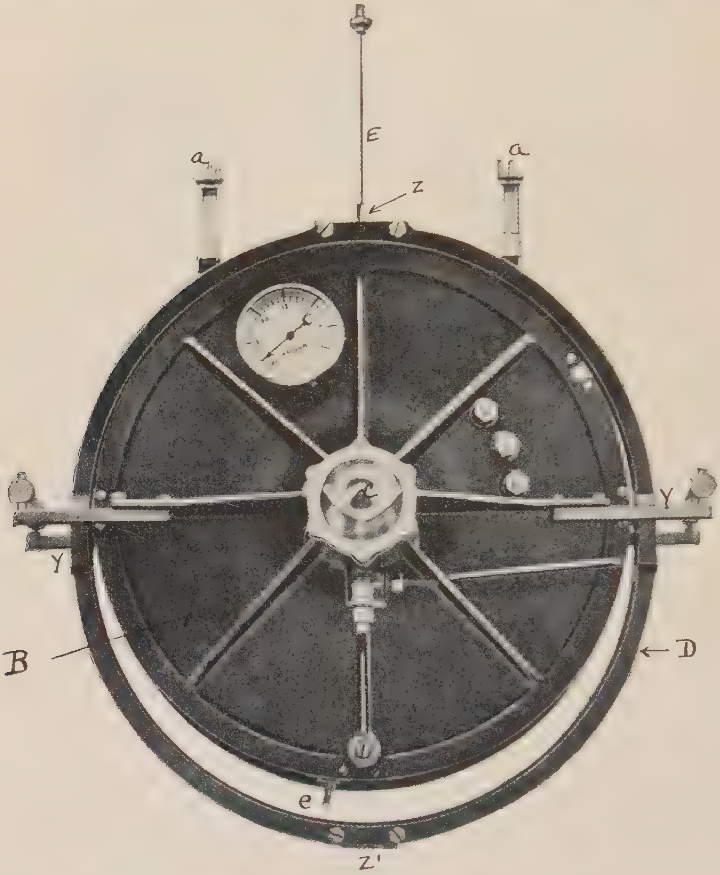


FIG. 281.—Sensitive Element, North Elevation, Showing Supports for Trolley Wheels *a*, *a*.

fore, when there is no movement of the element, the azimuth motor is continually moving the phantom, first one way and then the other through a small fraction of a degree. This makes the follow-up motion very sensitive and the lag of the phantom behind the element does not exceed $\frac{1}{4}$ of a degree. In the actual compass the trolley wheels *a* carry only a small pilot current which operates a relay (shown in Fig. 280) that controls the motor circuits. This is necessary because the trolleys are continually making and breaking the circuit, and the current must be reduced to the lowest possible intensity to prevent pitting. To reduce oxidation the wheels are made of either silver or gold.

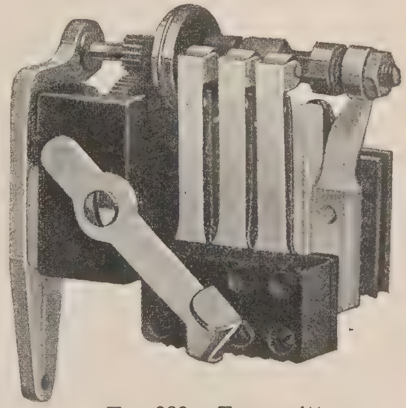


FIG. 282.—Transmitter.

The **transmitter** (Fig. 282) consists of the three movable contacts which are opened and closed by cams on the shaft. The shaft is geared to the phantom, and the transmitter itself is mounted on the movable lubber's ring of the master. Since all corrections are applied to the master by moving the lubber's ring, they are thus automatically applied to the repeaters; because movement of either the phantom or the lubber's ring operates the transmitter. The connection between the transmitter and one repeater compass is shown diagrammatically in Fig. 283. T represents the transmitter and P the pilot motor at the repeater. A movement of the transmitter shaft closes contact 1, energizing magnets 1 and 4, which draw the soft iron armature into the line between them. Further movement of the shaft closes contact 2, energizing magnets 1, 2, 4 and 5, causing the armature to move one-half pole pitch. Next contact 1 opens, and the armature sets itself between magnets 2 and 5. Next contact 3 closes, and so on, causing continuous rotation of the armature of the repeater in step with the shaft of the trans-

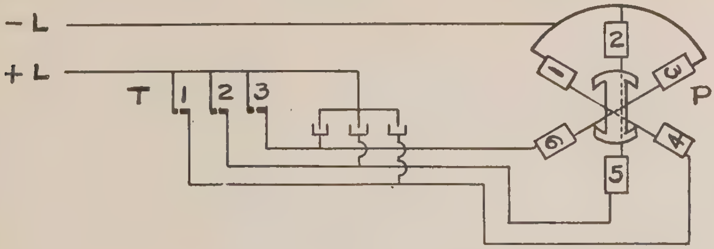


FIG. 283.—Elementary Diagram of Transmitter Circuits.

mitter. The armature shaft is geared to a disc carrying a compass card, which accordingly registers the angle between the lubber's line and the axis of spin of the master compass. This is the true course of the ship.

The condensers across the contacts in Fig. 283 absorb the spark that would otherwise occur at break.

Only one repeater compass is represented in Fig. 283, but in practice several are connected in parallel to the one transmitter.

The Synchronizer.—This is a device used to set the repeaters in step with the master. The necessity for it may be shown by an example, as follows: Suppose the master compass is started while reading 0° and the transmitter is energized with a repeater reading 15°. This repeater will thereafter follow every movement of the master, but will have a constant error of 15°. The repeater is not in the vicinity of the master, so it cannot be set by the simultaneous observations of both. Therefore, a device is necessary that will enable an operator at the master compass to set any one or all of the repeaters to the same reading as the master, without actually seeing the repeaters.

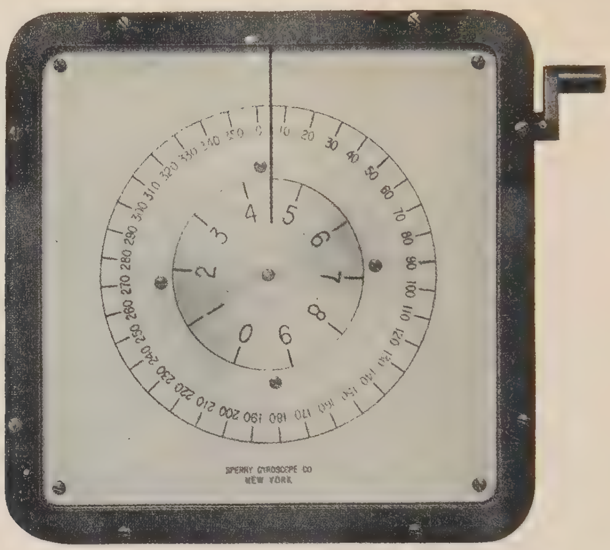


FIG. 284.—Synchronizer.

The device that accomplishes this is called the synchronizer. Its appearance is shown in Fig. 284. The case contains a transmitter exactly like that in Fig. 282, but driven by hand by means of the small crank at the upper right-hand corner. This transmitter operates the scale shown in the front of the case, the outer circle being geared 36 to 1 to the inner dial. The inner dial is for close reading of small angles; as shown, it registers 4° 30′. The synchronizer transmitter may also be connected so as to operate any one or all of the repeater compasses, its own scale then indicating the movement of the repeaters.

The circuits necessary for synchronizing one repeater are shown in Fig. 285. T is the main transmitter driven by the phantom. ST is the synchronizer transmitter explained above. M is the **stop magnet** at the repeater, which is energized by closing the switch MS. When energized, M raises a plunger which makes contact with lug C on the repeater compass card. When the plunger is up, the pilot motor can move the compass card until it reads 0°; then C comes in contact with the plunger and no further movement of the pilot motor can take place. Thus, by operating the synchronizer transmitter with the switch MS closed until the synchronizer scale has moved through at least 360°, the operator is assured that the repeater is set at 0°.

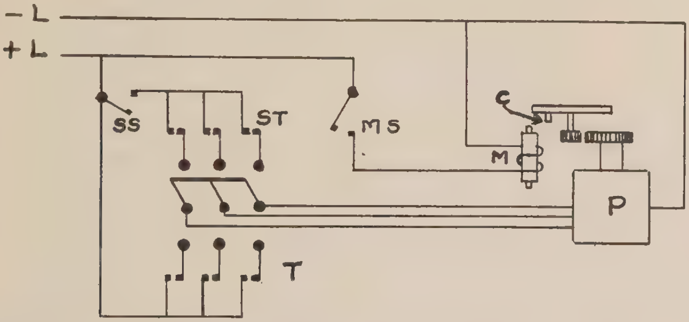


FIG. 285.—Elementary Diagram of Synchronizer and Main Transmitter Circuits to One Repeater.

The operation of synchronizing one repeater may be followed from Fig. 285.

1. Close SS, energizing the synchronizer.
2. Close MS, energizing the stop magnet.
3. Throw the 3-pole switch to ST, disconnecting the repeater from the main transmitter and connecting it to the synchronizer transmitter.
4. Operate ST by hand until the synchronizer dial shows a movement of at least 360°, thus setting the repeater at 0°.
5. Continue operating ST until the synchronizer dial also reads 0°.
6. Open MS. Further movement of ST will cause both repeater compass and synchronizer dial to move in step with one another.
7. Operate ST until the synchronizer dial reads the same as the master compass, then quickly throw the 3-pole switch to T. The repeater is now in step with, and driven by, the master.

In the actual installation, one synchronizer is supplied, and one or more of the repeaters may be connected to it at will, a 7-pole switch being provided for each repeater. This switch is represented by the 3-pole switch in Fig. 285, the other four poles carrying (1) the negative lead to the pilot motor, (2) the lead to the stop magnet, (3) a pilot lamp at the repeater, which illuminates the scale and shows that it is energized, and (4) return wire for circuits (2) and (3).

Electric Circuits.—The essential electric devices described above are:

1. The master gyro, 3-phase, alternating current, 90 volts.
2. The stabilizer gyro, 3-phase, alternating current, 10 volts.
3. The azimuth motor, 20-volt, direct current.
4. The transmitting system to the repeaters, 20-volt, direct current.

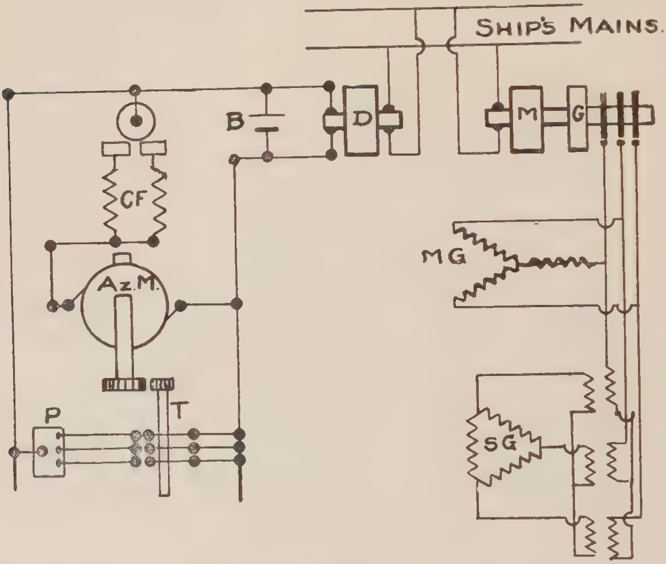


FIG. 286.—Elementary Diagram of Power Circuits of the Sperry Compass.

Fig. 286 is an elementary diagram of the circuits required to operate this apparatus. The alternating-current circuit is supplied by the motor generator MG. M is a bipolar compound-wound motor, taking current from the ship's mains. G is an 8-pole inductor alternator. The stators of main and stabilizing gyros and the transformer are indicated. The motor has no starting resistance and can be thrown directly across the line without damage. Its speed is regulated by a shunt field rheostat (not shown). The main gyro's speed varies almost directly as the frequency of the alternator, and since the various corrections of the compass assume a constant precessional force, which depends on constant speed of the wheel, the speed of the motor must be kept constant. The maximum output of the alternator is about three amperes.

The direct current is supplied by a shunt-wound dynamotor driven from the ship's mains. The low-voltage end is rated at 24 volts, giving a terminal E. M. F. of 22 volts. A 10-cell storage battery B is floated on the line. This battery is rated at 20 volts, but at full charge the E. M. F. would be about 25 volts, consequently, if run down, it is charged by the dynamotor to the line voltage, and then neither takes nor gives current. Its function is to operate the azimuth motor and the transmitter in case of failure of the dynamotor or of the ship's circuits. The inertia of the main gyro will keep it spinning for several hours after power is cut off, and the storage battery insures operation of the rest of the compass equipment in such case.

The transmitter is indicated as geared directly to the azimuth motor. Actually it is driven by the phantom which in turn is driven by the motor. P represents a repeater compass.

Protective Devices.—The following derangements may occur:

1. The dynamotor may stop due to failure of line voltage or faults in the machine itself. In this case the storage battery will supply the direct-current circuit, but it would also rapidly discharge through low resistance of the dynamotor. To prevent this an automatic device cuts out the dynamotor when its voltage falls, and also rings an alarm bell.

2. The azimuth motor may fail. In this case the phantom no longer follows the sensitive element. Mechanical contacts cause an alarm bell to ring when this occurs.

3. The alternating-current motor generator may slow down due to lowering of the line voltage. This will decrease the frequency and voltage of the alternator, and will slow down the main gyro; because its speed depends on the frequency. Therefore, a device is provided to open the field circuit of the alternator and ring an alarm gong when it slows down. The inertia of the main gyro will keep it spinning at nearly full speed if it is free to do so, but if the stator frequency decreases it will act as an inductor generator and its speed will decrease rapidly in consequence. The opening of the alternator field by the emergency device de-energizes the gyro stator and allows the wheel to spin freely.

4. The vacuum in the gyro case may be lost by leakage. This is indicated by slowing of the wheel and increase in the current. The gyro may be run at reduced speed (about 7000 R. P. M.) in this condition, an adjustable resistance in the field circuit of the alternator permitting an increase in its voltage. The slowing of the wheel introduces a small error.

Fig. 287 is an elementary diagram showing the alarm and cut-out circuits.

1. The no-voltage coil NV and the reverse-current coil RC are wound on a single core. Normally the flow of current through these coils is as indicated by arrows, and the armature of the coil is lifted up and completes the dynamotor circuit. If the dynamotor fails, current flowing back through it from the battery reverses its direction in RC; the two coils cancel the magnetic effect of one another; the armature falls, and breaks the circuit to the dynamotor and current no longer flows in either coil. If the dynamotor starts again, current flows through NV, raising the armature and re-establishing the dynamotor circuit. In falling, the armature makes contact at Q. This completes a circuit through the 6-volt battery B′ and the alarm relay L. This attracts armature W, and the alarm bell J rings.

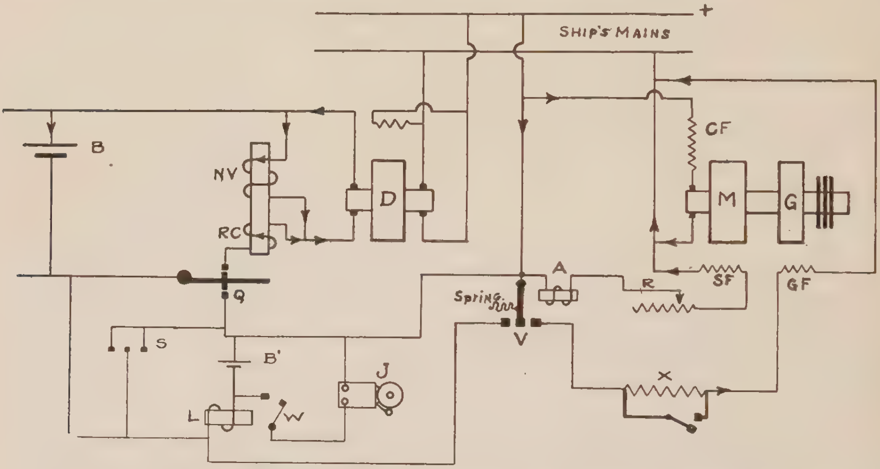


FIG. 287.—Direct Current Power Circuits, Cut Outs, and Alarm Circuits.

2. If the phantom fails to follow the element, the device marked S becomes operative. The central contact is fixed to the element and the two side contacts are fixed to the phantom. Therefore, if the element moves without the phantom closely following, circuit is made through the alarm relay by this device, ringing the alarm gong.

3. The shunt field circuit of the motor of the motor generator forms a coil at A which controls a contactor V in the alternator field circuit. If the voltage of the line falls, this coil releases the contactor, breaking the alternator field circuit and closing a circuit through the alarm relay.

Only one alarm bell is provided. If it rings, the circuit affected may be located by ammeters. If the alternating-current and direct-current circuits are carrying rated current, the trouble is evidently in the follow-up motion of the phantom.

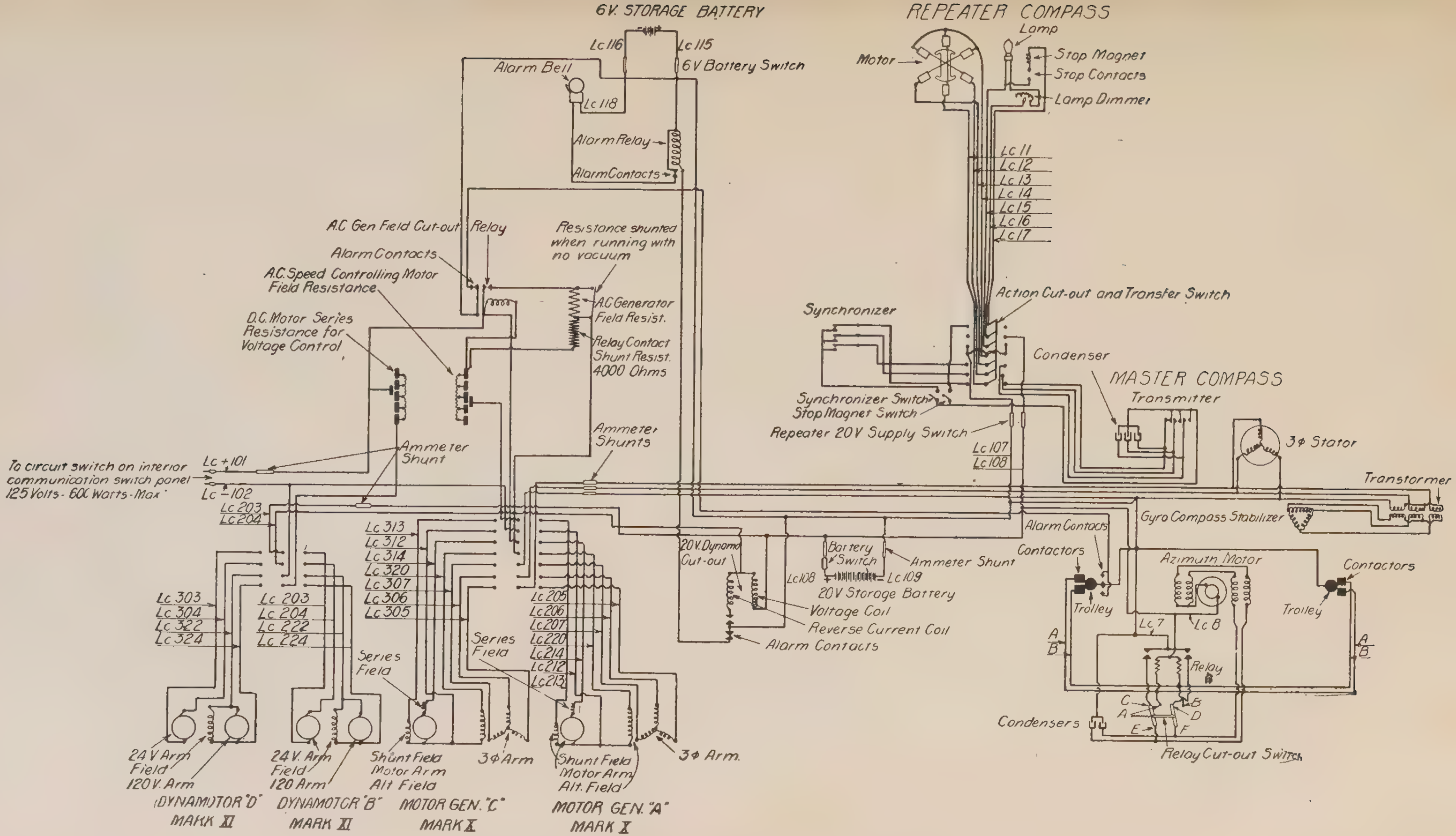

6V. STORAGE BATTERY
Lc 116
Lc 115
6V Battery Switch
Alarm Bell
Lc 118
Alarm Relay
Alarm Contacts
REPEATER COMPASS
Lamp
Motor
Stop Magnet
Stop Contacts
Lamp Dimmer
Lc 11
Lc 12
Lc 13
Lc 14
Lc 15
Lc 16
Lc 17
A.C Gen Field Cut-out
Relay
Alarm Contacts
A.C. Speed Controlling Motor Field Resistance
Resistance shunted when running with no vacuum
A.C Generator Field Resist.
Relay Contact Shunt Resist. 4000 Ohms
D.C. Motor Series Resistance for Voltage Control
Action Cut-out and Transfer Switch
Synchronizer
Condenser
MASTER COMPASS
Transmitter
Synchronizer Switch
Stop Magnet Switch
Repeater 20V Supply Switch
Lc 107
Lc 108
3φ Stator
Transformer
Ammeter Shunt
Ammeter Shunts
To circuit switch on interior communication switch panel 125 Volts - 60C Watts - Max
Lc +101
Lc -102
Lc 203
Lc 204
Gyro Compass Stabilizer
Alarm Contacts
Contactors
Trolley
Azimuth Motor
Lc 8
Lc 7
Contactors
Trolley
20V. Dynamo Cut-out
Battery Switch
Ammeter Shunt
Lc 108
Lc 109
20V Storage Battery
Voltage Coil
Reverse Current Coil
Alarm Contacts
A
B
Relay
A
B
C
A
B
D
E
F
Condensers
Relay Cut-out Switch
Lc 313
Lc 312
Lc 314
Lc 320
Lc 307
Lc 306
Lc 305
Lc 303
Lc 304
Lc 322
Lc 324
Lc 203
Lc 204
Lc 222
Lc 224
Lc 205
Lc 206
Lc 207
Lc 220
Lc 214
Lc 212
Lc 213
Series Field
Series Field
24V Arm
Field
120V. Arm
24V. Arm
Field
120 Arm
Shunt Field
Motor Arm
Alt Field
3φ Arm
Shunt Field
Motor Arm
Alt. Field
3φ Arm.
DYNAMOTOR "D"
MARK II
DYNAMOTOR "B"
MARK II
MOTOR GEN. "C"
MARK X
MOTOR GEN. "A"
MARK X

FIG. 288.—Circuits of the Sperry Gyro Compass.

4. X is a resistance in the circuit of the alternator field GF. If the vacuum in the case is lost, this resistance may be short circuited by the switch shown.

Electric Circuits in Detail.—Fig. 288 is an elaboration of the preceding elementary diagrams and shows the actual circuits in the Sperry compass equipment. There are two dynamotors and two motor generators, duplication of these machines being usual to minimize the chances of break downs. Only one dynamotor and one motor generator are in use at any one time.

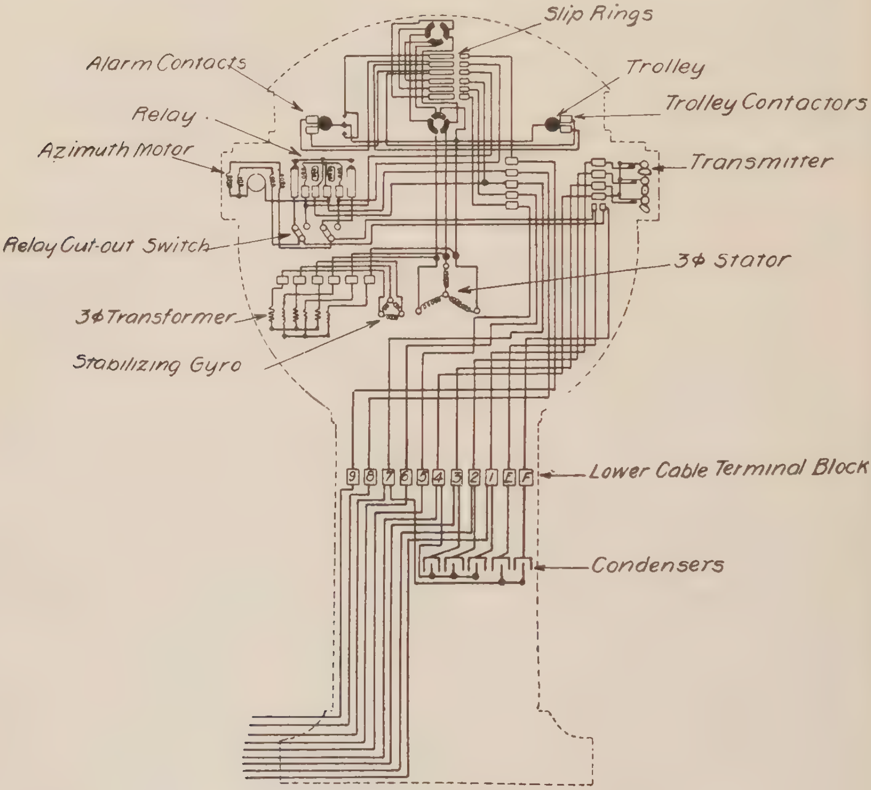

Slip Rings
Alarm Contacts
Trolley
Trolley Contactors
Relay
Azimuth Motor
Transmitter
Relay Cut-out Switch
3ϕ Stator
3ϕ Transformer
Stabilizing Gyro
9 8 7 6 5 4 3 2 1 E F
Lower Cable Terminal Block
Condensers

FIG. 289.—Interior Wiring of the Master Compass.

Fig. 289 is a diagram of the wiring in the master compass. The relay cut-out switch (shown below the azimuth motor relay) connects the trolley contacts either to the pilot circuits of the relay, or directly to the motor. If the relay fails, the motor current may be taken directly through the contacts by throwing this switch. It also permits removal of the relay for examination and cleaning without stopping the compass. As previously explained, the trolley contacts will be damaged by heavy current too long continued. So the relays should be cut out only when necessary and then for as short a time as possible.

The Automatic Voltage Regulator.—The motor of the motor generator must have a constant speed to insure proper action of the compass. With the practically constant voltage of the ship's mains there is no trouble from this source, but when the compass is used on a submarine, a converter is necessary to change the constantly varying E. M. F. of the storage battery to a steady E. M. F.

This is accomplished by a motor generator with voltmeter control, furnished as a part of the compass equipment for submarines.

Fig. 290 is an elementary diagram of this machine. M is a shunt-wound motor designed for operation on a range of voltage from 100 to 160; its speed, of course, varying with the voltage. It drives the compound-wound generator G. CF is the series field and f_2 and f_1 are shunt field coils in series with the resistance R_4. A is the armature of the voltmeter controller, pivoted between two poles wound in series across the leads L, L′. The spring S holds the armature against contact C_1 when there is no current in the coils. When the E. M. F. across L, L′, reaches 120 volts, A is deflected and touches neither contact. When the voltage is above 120, the armature touches the contact C_2.

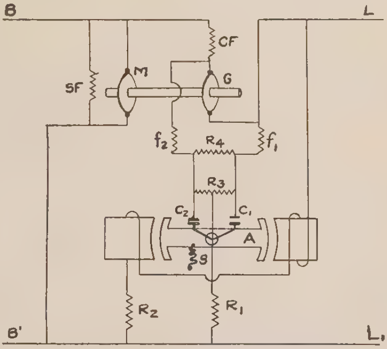
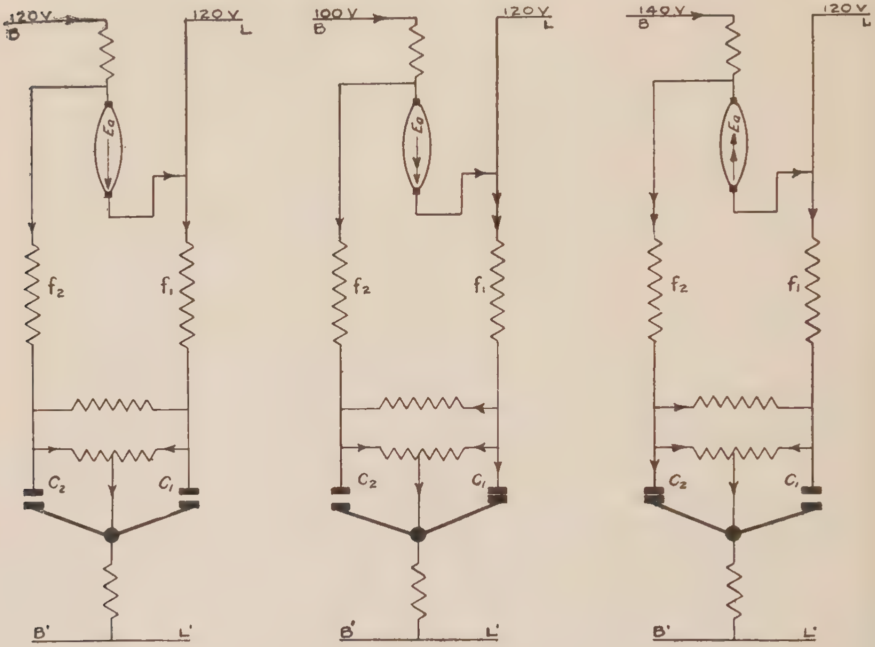


FIG. 290.—Elementary Diagram of Sperry Voltage Regulator.

OPERATION.—The mains, B, B′ lead to the storage battery. The mains L, L′ lead to the compass dynamotor and motor generator. The function of the machine is to maintain 120 volts across L, L′ regardless of variations in the voltage across B, B′. The line B′L′ is of small resistance and the RI drop in it is negligible. Therefore, B′ and L′ will be always at the same potential. Assume this line to be always at 0 volts. Then the E. M. F. between mains may be expressed by giving an absolute value to the voltage of the + line. B and L are not necessarily at the same potential because between B and L there is the IaRa drop through the generator G and the Ea of G.

Referring to Fig. 291a, it is assumed that current is supplied at 120 volts and that the regulator voltmeter is touching neither contact. Current flows clockwise in field f_2 and anticlockwise in f_1. A clockwise flow of current in either of these fields opposes the series field, and an anticlockwise flow assists the series field. In this case the two fields f_2 and f_1 cancel each other, and the generator Ea depends only on the series field, and is just sufficient to compensate for the RI drop in the series field and armature windings. Thus there is no change in the voltage of the current as it flows through G, and B and L are at the same potential.

Now suppose that the supply voltage suddenly falls to 100 as represented in Fig. 291b. The voltage at L tends to fall also, but as soon as it drops below 120, the regulator armature closes contact C_1. This gives a low resistance path through field f_1, and the current in it promptly increases, assisting the series field. Ea consequently increases, so there is a rise in voltage through the generator, the motor supplying the necessary power. When the voltage rise through the generator becomes 20 volts, contact C_1 opens. Ea then begins to decrease, and C_1 closes again. C_1 is, therefore, constantly opening and closing and the voltage in L is constantly vibrating through a very small range, the effect being a practically constant E. M. F. of 120 volts at L.



a b c

FIG. 291.—Action of the Voltage Regulator.

In Fig. 291c, the supply voltage is represented as suddenly increasing to 140. f_2 now becomes the stronger field, on account of the closing of contact C_2. It overpowers the series field and reverses the armature flux and Ea.

Now the current in passing through the generator suffers not only an IR drop, but also a drop equal to Ea. C_2 will rapidly open and close, as did C_1 in case *b*, maintaining the voltage at L at a practically constant value of 120. In this case G becomes a motor and, if its torque is sufficient, drives M as a generator. If the torque of G is small, both M and G act as motors, the load being the stray loss of the two.

Resistances R_4 and R_3 regulate the relative values of the current in f_2 and f_1 to the proper value. R_2 regulates the current through the controller poles, and R_1 prevents excessive current from flowing in either f_2 or f_1, these having but small resistance.

CHAPTER XXII.

ELECTRICAL EQUIPMENT OF SUBMARINES.

The electrical machinery installed on board submarines is of the same general type as that used elsewhere in the Navy; except that the extremely restricted space, the necessity for saving in weight, and the presence of inflammable gases from the storage battery require that special attention be given to making the electrical equipment as light and as compact as possible, and protected against the danger of gas explosions.

Motors, unlike those of surface vessels which are supplied at a practically constant terminal E. M. F., are designed for operation through the wide range of voltage supplied by the storage batteries. For the auxiliary motors, it is usual to use 60 cells, which give from 102 to 162 volts, depending on the state of charge of the batteries, provided that only a small amount of current is being delivered. When the batteries are being charged and are at the end of the charge, the upper limit is still further increased; and towards the end of a discharge at a high rate, the lower limit is decreased. In most cases no attempt is made to compensate automatically for this varying voltage, and motors whose service requires constant speed must be regulated by the attendants as the battery voltage changes. It is, however, necessary that shunt fields have sufficiently low resistance to take the proper exciting current at the lowest voltage, and that the field rheostats have sufficient range of resistance to regulate the field current from the lowest to the highest voltage. These wide-range shunt field rheostats are one of the distinguishing features of motor equipment designed for submarines.

ARRANGEMENT OF PROPELLING MACHINERY.

The details of submarine machinery are confidential and only a general description can be given here.

The propelling machinery consists usually of two internal-combustion engines, each driving one propeller shaft. Mounted on each shaft are one or more motors taking current from storage batteries and so arranged that they can be driven as generators by the main engines to charge the batteries. A typical arrangement of one shaft is shown in Fig. 292. C is the main clutch, located between the engine and the motor, and T is the tail clutch between the motor and the propeller. The motor armature is keyed to the shaft.

For surface running both clutches are engaged and the armature circuit of the motor is opened, so that the armature turns idly and acts as a fly wheel for the engine.

For submerged running the tail clutch T is engaged and the main clutch C is thrown out, disconnecting the engine; the motor then drives the shaft.

To charge the batteries the tail clutch is thrown out and the main clutch is engaged; the engine then drives the motor as a generator; it is, of course, necessary to regulate the speed and field current so that the armature voltage will be greater than that of the batteries.

It is also possible to charge batteries while cruising on the surface by simply exciting the motor field and closing the battery switches, but the power of the engines is sufficient for only a very low charging rate in this condition, and this method is usually employed only to keep a charged battery full, by supplying just enough current to make up for that taken by the electric auxiliaries while cruising.

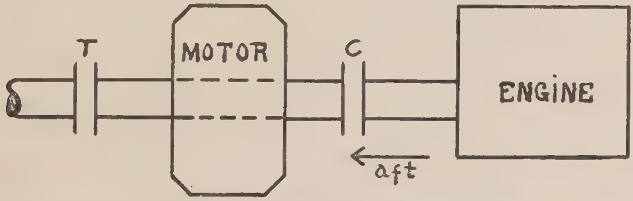


FIG. 292.—Arrangement of Machinery on One Main Shaft of a Submarine.

STORAGE BATTERIES.

The accumulator usually consists of 120 cells, giving an *average* voltage during discharge of 240, when all cells are connected in series. The weight of the batteries is a large proportion of the displacement of a submarine and must be located below the center of gravity to insure stability. Consequently, in most cases, the accumulator is placed beneath the working deck in the midships' compartment. The cells are carried in lead-lined steel tanks, great care being necessary to prevent acid from getting into the bilges where it will attack the plating. The usual practice is to divide the cells down the longitudinal center line of the boat; all those on the starboard side being permanently connected in series to form one battery, while those on the other side are similarly connected to form the port battery. The system of compensating for voltage drop by means of end cells is not used with the batteries of submarines.

Plates.—The iron-clad type of plate is very commonly used for positives. Negatives are usually of the pasted type. Some batteries have Planté positives and pasted negatives; and some are fitted with pasted plates only.

Battery Conductors.—All conductors within the limits of the batteries are made of a core of bar copper, to give strength and conductivity; and the bar is covered with a thick coating of lead to resist the corrosive action of the electrolyte. Connections are made by placing two such conductors in contact and melting the lead on each with a hydrogen flame; the melted lead flows together and, when cool, forms a solid joint of low resistance. The process is known as **lead burning**.

Construction of Cells.—The container is a jar of hard rubber. The plates are lead burned to bus bars, and the busses are in turn burned to terminal bars; the positive plates in one cell being mechanically connected to a bus bar, and the negative plates to another bus bar. The plates hang from their bus bars, having no bottom supports, and are packed fairly tightly in the cells to prevent surging in a sea way. To prevent contact between plates, sheets of perforated hard rubber, known as **sheet separators**, are placed between them; these are strengthened by vertical strips of hard rubber, known as pin separators. The pin separators are split, except for a short distance at the top, and fit over the sheet separator, as shown in Fig. 293. The sheet separators are longer than the plates and rest on hard-rubber supports, on the bottom of the cell. A space of several inches is left between the floor of the jar and the bottom of the plates, where the sediment which gathers from dirt in the electrolyte and active material thrown off by the plates may collect.

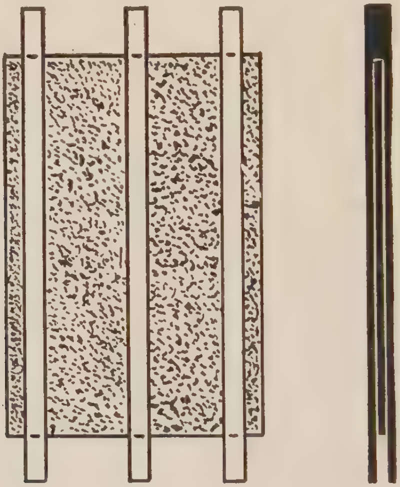


FIG. 293.—Sheet Separator with Pin Separators Attached.

The cell is closed by a hard-rubber cover to keep out water and dirt. In the cover there is an air duct leading to a suction blower, a vent for intake of air, and a hole, closed by a screw cap, which permits access to the cell to take hydrometer readings and to add water to the electrolyte.

Each cell has leads to a voltmeter switch, by means of which the voltage of any cell may be read from the voltmeter on the switchboard.

Rating of Cells.—A cell is rated by the number of plates it contains, a 27 W cell being one 27 plates wide. Plates were for sometime made in two lengths only, the longer size being denoted by the letter L as 27WL. There is always an odd number of plates in a cell, because the two outside plates are active on one side only; the surface next the jar undergoing but little chemical change. Consequently, plates of the same polarity are used for the two outsides, their two "live" surfaces being equivalent to one plate with both its surfaces active. The outside plates are exposed to severe strains from the unequal expansion of the two surfaces, and, consequently, negative plates are usually used at the extremities of a cell, the negatives being less subject to change in volume than the positives during the cycle of a charge.

Electrolyte.—The electrolyte used is sulphuric acid diluted with water. The density of the electrolyte is of great importance. If too rich in SO_4 the plates sulphate very rapidly when partially discharged; if too weak the capacity of the battery is low. Less dense electrolyte may be used in warm weather than in cold, because, when hot, the active material of the plates expands and its pores open and the weaker electrolyte acts with greater facility. Submarine batteries are, therefore, in order to secure the greatest capacity possible without excessive sulphation, normally kept at a specific gravity of 1.260 times that of water, when the battery is fully charged and at 80° F. Vessels operating continually in the tropics use a specific gravity of 1.210 on full charge at 80° F. The specific gravity when discharged varies with the rate of discharge. The drop in gravity is much greater than in a small cell, because the amount of electrolyte is relatively less; at the three-hour rate, for example, a submarine battery may fall from 1.260 to 1.190.

Battery Connections.—All the positive plates in any one cell are permanently connected in parallel; and the negatives likewise. Therefore, the voltage per cell is the voltage between two plates.

All the cells in one battery are permanently connected in series, so the voltage per battery is the voltage between two plates times the number of cells in the battery. There are usually 60 cells in one battery.

The two batteries may be connected either in series or in parallel with one another. The parallel connection gives a low voltage and low internal resistance for slow speeds; while the series connection gives a high voltage for fast speeds, but at a sacrifice in efficiency due to the increased internal resistance.

Battery Construction.—The batteries are enclosed in a steel tank, lined with lead. The tank is divided into a number of compartments by wooden partitions, and one cell fits tightly into each compartment. The entire tank is covered with a battery deck, made of removable wooden battens, covered with sheets of heavy rubber to exclude moisture, and with shellacked canvas to protect the rubber covers. Cables are lead burned to the terminals of the cells at the end of each battery, and connect to the switchboards.

Battery Ventilation.—It is extremely important that the gases generated in the cells be removed before the percentage of hydrogen becomes large enough to be explosive. For this reason air is continually circulated through the cells, over the tops of the plates. Each cell has an air intake vent in the cover, which draws air from the space below the battery deck. A suction blower is connected to another vent in each cell and draws out the mixture of air, oxygen and hydrogen. The blowers are arranged to discharge overboard when the boat is on the surface and into the upper part of the hull when submerged. A mixture of air with 4 per cent free hydrogen is explosive, so the inboard discharge of the ventilators will in time render dangerous the atmosphere of the submarine. However, the batteries do not evolve much gas when discharging, and the vessel is always on the surface when charging; so the usual operations of the submarine are not interfered with, provided that the ventilating apparatus is properly used.

Switchboards.

Current from the storage batteries is distributed through two switchboards, usually mounted side by side on a common foundation. The main switchboard supports the connections leading to the main motors only, while the auxiliary board carries all the other circuits.

A typical arrangement of the switchboards is shown in Fig. 294. The two storage batteries are represented at the bottom of the figure, with positive and negative leads from each connecting to terminals on each switchboard.

Main Switchboard.—On the main board four vertical fused bus bars connect to the terminal block of a D. P. D. T. switch, which in the position shown connects the two batteries in parallel to the two motors. Throwing the switch to the other position connects the batteries in series. Above the series-parallel switch is a voltmeter switch V*s* which is connected to the voltmeter V′ on the auxiliary board and may be manipulated so as to cause V′ to indicate the voltage across the terminals of either battery or either main motor, the voltage from any battery terminal to ground, or the voltage of the lighting circuit. Four lamps (not shown) are also provided as battery ground detectors. From the shunts, marked A. H. S., circuit is made to the two ampere-hour meters H, each of these registering the quantity of electricity flowing through the main switchboard from or to one battery.

Auxiliary Switchboard.—The auxiliary switchboard carries a vertical row of circuit switches hinged to the terminals of the auxiliary circuits. Vertical bus bars from the battery terminals are so arranged that throwing a switch to the right connects that circuit to one battery, while throwing it to the left connects it to the other. The auxiliary circuits are for lighting, heating, cooking, signaling, search-light, auxiliary motors, and the shunt fields of main motors. V is a low-reading voltmeter with a switch to connect it across the terminals of any cell, V′ is the voltmeter connected to Vs on the main board and H′, H′ are ampere-hour meters, one in the circuit of each battery.

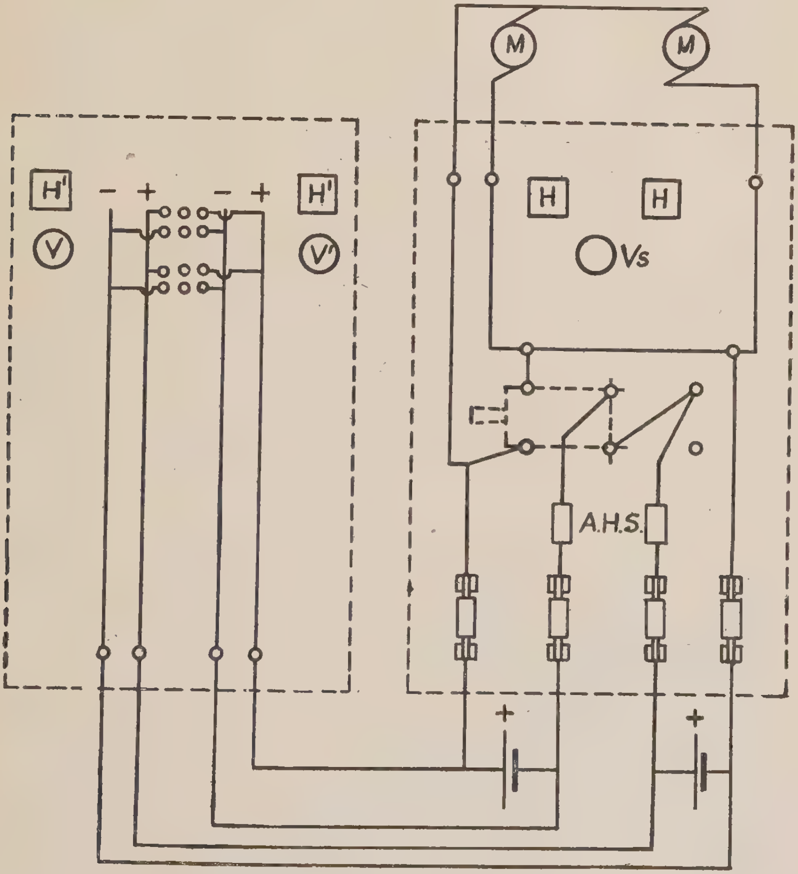


FIG. 294.—Auxiliary and Main Switchboards.

The readings of the four ampere-hour meters if properly used will give approximately the condition of charge of each battery. As a battery is charged, its meter on the main switchboard will record the ampere-hours delivered to its terminals, and its meter on the auxiliary board will record the ampere-hours taken out by the auxiliaries, the difference between these two readings giving the quantity supplied to the battery. As the battery discharges, the ampere-hours delivered will be indicated by the sum of the readings of its main and auxiliary meters. Thus the ampere-hours available in the battery may be readily calculated at any time, it being, of course, necessary to apply a correction for loss due to gassing, heating, grounds and local action, as determined by experience with the plant.

MAIN MOTORS.

Shunt-wound motors are used exclusively for the propulsion of submarines; a series winding is added, in some cases, to the field in order to improve commutation and to stabilize the speed.

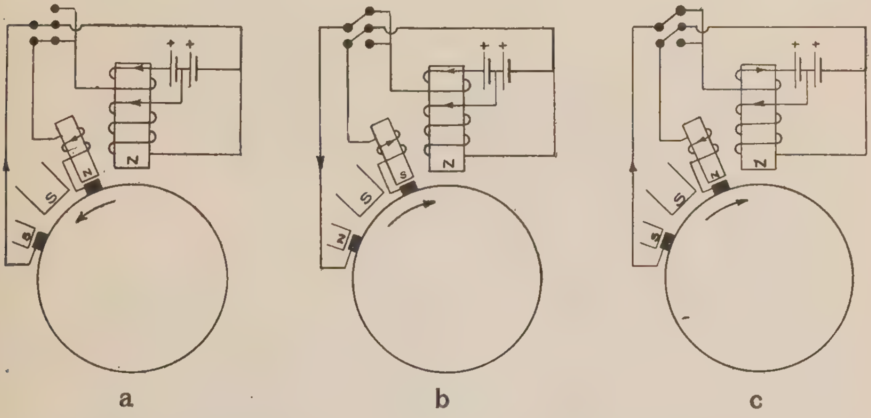
The shunt winding, instead of being connected across the brushes in the usual manner, is connected to the terminals of *one* battery. As previously explained, the shunt-field circuits originate on the auxiliary switchboard, where they may be connected to either battery. The field circuits of the two motors are separate, and each has a field rheostat, located at the motor control station.

The conditions of commutation are very severe. The terminal E. M. F. varies from about 100 volts with the batteries in parallel and nearly discharged, to over 300 volts with series connection and full charge. The machines must operate as reversible motors, or as generators, through wide ranges of speed and load. The pressing necessity for reduction in weight requires that, at maximum load, the machines be operating at the maximum capacity. And the necessity for reduction in size requires that the pole spacing be small. It is essential that speed changes be made rapidly, so it is desirable that no shifting of the brushes be required.

The following summarizes the ways in which these conditions have been met:

Plain Shunt Winding.—In earlier construction the field was excited by a shunt winding only. Later, interpoles were adopted to minimize brush shifting. These motors are not very powerful for their weight and the space occupied because, even with interpoles, there is considerable armature reaction.

Stabilized Shunt Winding.—Increasing the power of the motors on more modern submarines has resulted in a very compact construction, which reduced the pole spacing to such a degree that a stabilizing winding became necessary. One or two turns of series winding are wound on each main pole in such a way as to act cumulatively when the machine is operating as a motor, and differentially when the machine is operating as a generator. Fig. 295 shows the elementary connections necessary to fulfill these conditions. For the sake of clearness only one main and one auxiliary pole are shown. Actually the series coils of all main poles are in series, and shunt coils and auxiliary coils are similarly connected. Also all brushes of one sign are in parallel. The action of the stabilizing winding on motors has been explained in Chapter III. The series field is connected differently when the dynamos are acting as generators in order that changes of speed, which are continually occurring in the internal-combustion engines, may not cause fluctuations in the charging current. An increase of speed raises the voltage, which increases the current through the series coils, which in turn weakens the field; the action tending to prevent large changes in current.



a. As motor, backing. *b.* As motor, ahead. *c.* As generator. (In *a* and *b* field coils are cumulative; in *c* they are differential.)

FIG. 295.—Field Circuits, Shunt Motor with Stabilizing Coils.

The stabilizing winding on the motors of submarines consists of only one or two turns per pole. Since the connections are the same as for a compound winding, the motor so wound is often called a compound-wound motor.

Compensating Winding.—The connections of two poles of a motor with compensating winding are shown in Fig. 296. Each pole consists of a shunt field core and a number of projecting pole pieces. A series field is wound on the pole pieces in a succession of spirals, called **compensating coils** or **balancing coils.** Each spiral commences with a coil around the pole piece midway between centers of the shunt field cores; this corresponds to an interpole, being directly over the armature inductors undergoing commutation. The spiral is then continued in a series of coils of increasing radii. The underlying principle is that, as illustrated in Fig. 296, each armature inductor that is carrying current has over it a series field conductor carrying an equal current in the opposite direction. Consequently, the magnetic action of the two is zero, and there is *no flux from the armature inductors* (neglecting leakage). The inductors shown in the center of each brush are carrying no current, but have a high inductive E. M. F. caused by the reversal of the current. As shown, the compensating winding supplies a commutating flux which neutralizes this E. M. F. It is proposed to use this type of field winding for the main motors of submarines. If properly designed, the armature flux and the effects of reactive voltage are negligibly small, and the armature current is then limited only by the carrying capacity of the armature winding; there being no sparking at the brushes for any conditions of field strength, armature current, or direction of rotation.

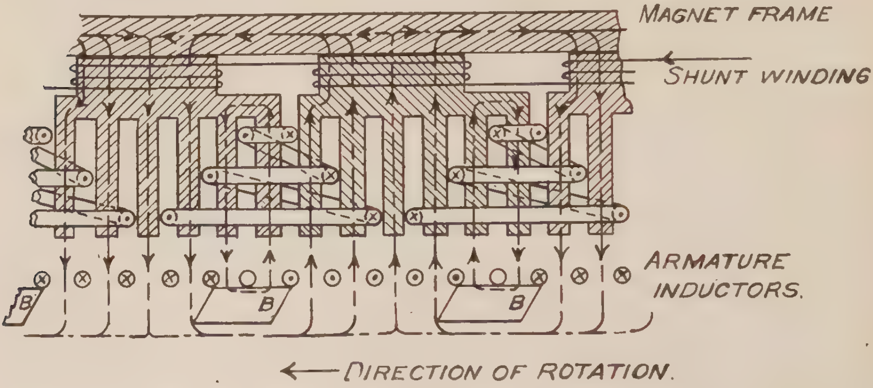


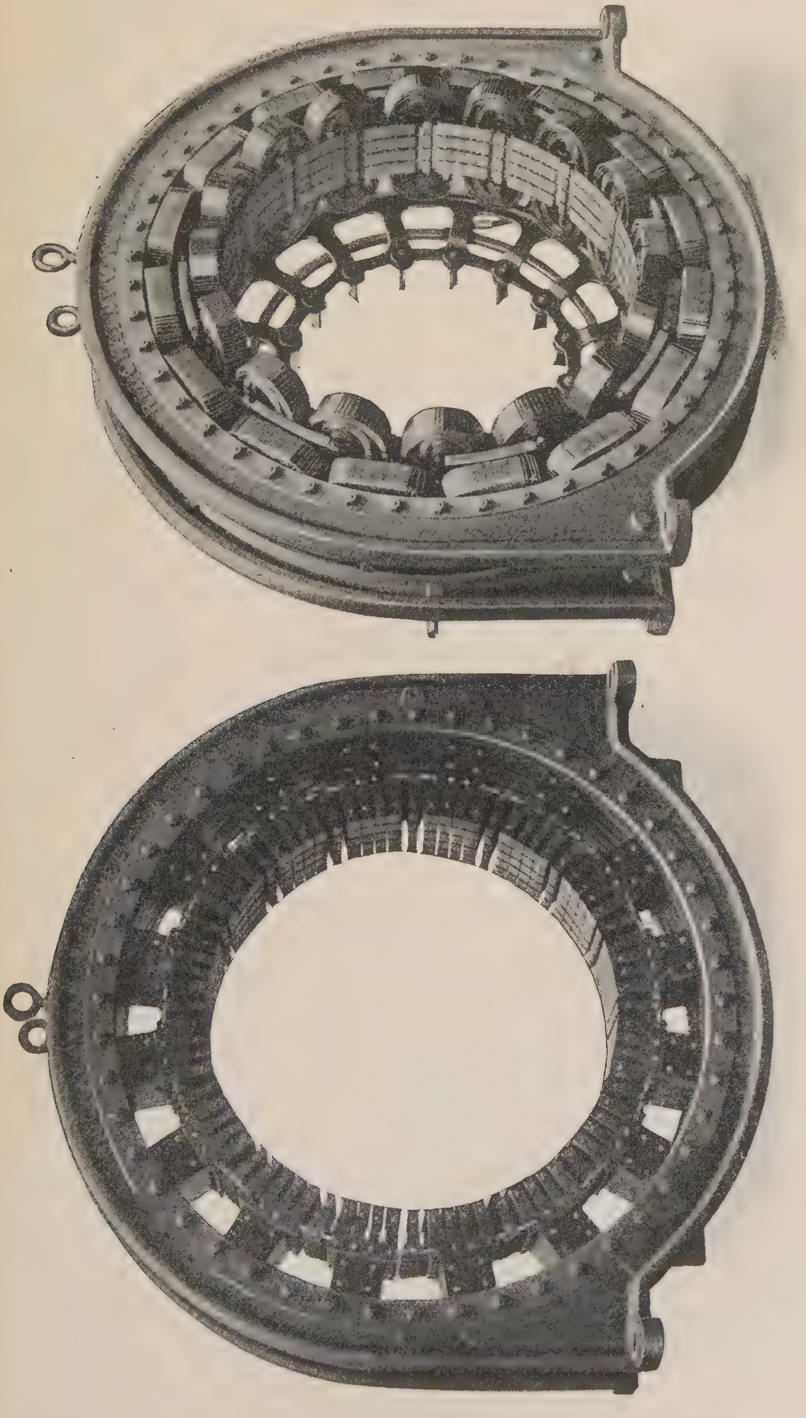
FIG. 296.—Compensating Winding for Motor Field.

Fig. 297 shows the actual construction of the field structure of a compensated shunt-wound dynamo, built by the Ridgway Dynamo and Engine Company.

Mechanical Construction.—The latest type motors are designed with the idea of reducing friction to a minimum and therefore are provided with grease-lubricated ball bearings.

They are located in the engine room, and are, therefore, totally enclosed as protection against oil and water which may be thrown off by the engines.

Since the capacity of the motors depends largely on the temperature the insulation can stand, adequate ventilation is essential. A ventilating duct leads from some part of the vessel where the air is cool and clean to the motor cover. Thence it passes through the ventilating slots in the armature spider, through and around the field coils, to a discharge duct at the top of the motor. The circulation of air is usually effected by the centrifugal action of the



A.—Field Ready to Wind.

B.—Field Complete, Rear View.

Fig. 297.—Dynamo Field.—Ridgway Dynamo and Engine Co.

armature, the air in the ventilating slots being continually thrown outward; this is known as the **self-ventilated system.** In some cases a suction blower is installed in the discharge duct to accelerate the circulation of air; this is known as the **separately ventilated system.**

MAIN MOTOR CONTROL.

The motors are controlled by starting resistance in the armature circuits which may be used for short intervals to control the speed when maneuvering. The principle speed control is by means of shunt field rheostats.

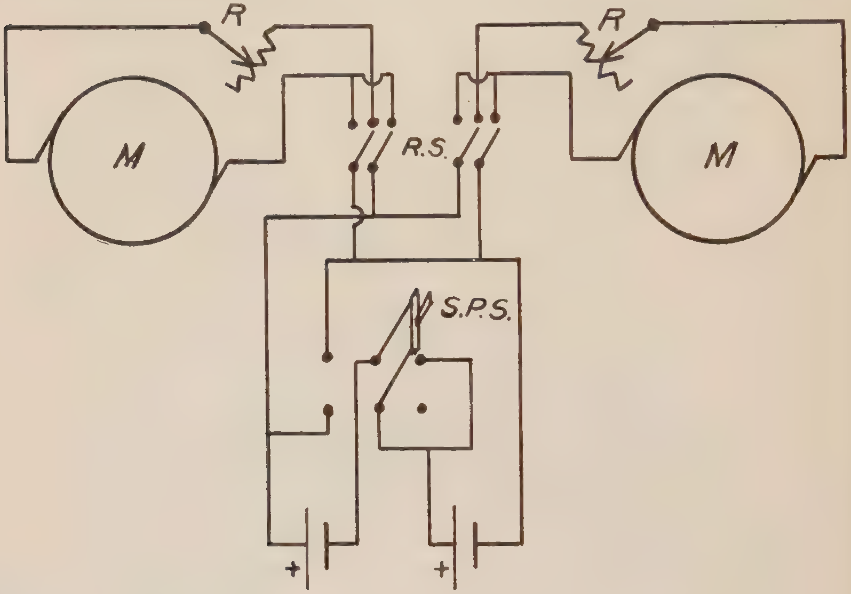


FIG. 298.—Elementary Diagram of Main Motor Circuits. Field Circuits Omitted.

An elementary diagram of the armature circuits of a two-motor, two-shaft installation is shown in Fig. 298. Current, after passing through the series-parallel switch, divides, part going to each motor; and each motor has a separate and independent reversing switch and starting rheostat. One motor may, therefore, be stopped, or going ahead or astern, at any speed regardless of what the other is doing, although both must be on either the high- or the low-voltage battery connection at any time.

In older vessels each motor has a D. P. D. T. knife switch for reversing, and the starting resistance is controlled by a number of lever switches operated by hand. Later submarines have reversing and starting switches of the contactor type mounted on a panel and controlled by a master drum, which may be located anywhere in the boat.

A typical starting panel is shown in Fig. 299. One of these panels is provided for each motor and is mounted in the engine room, the pilot circuits leading to a master controller in the operating compartment under the conning-tower. The master is a drum controller of the usual type and the action of the system is as follows:

To Go Ahead.—The operator moves the master controller to the first ahead position. This closes the pilot circuits of the line contactors F1 and F2 which close, feeding current to the motor through resistance 1. The next step on the controller energizes the actuating coils of clapper switch 2, closing it and allowing current to flow through resistances 1 and 2 in parallel. Successive steps on the controller close clapper switches 3, 4 and 5, and at the "full-on" position contactor 6 closes, providing a direct path for the current through conductor 6. Speed may then be regulated by the shunt field rheostat which is mounted near the master controller.

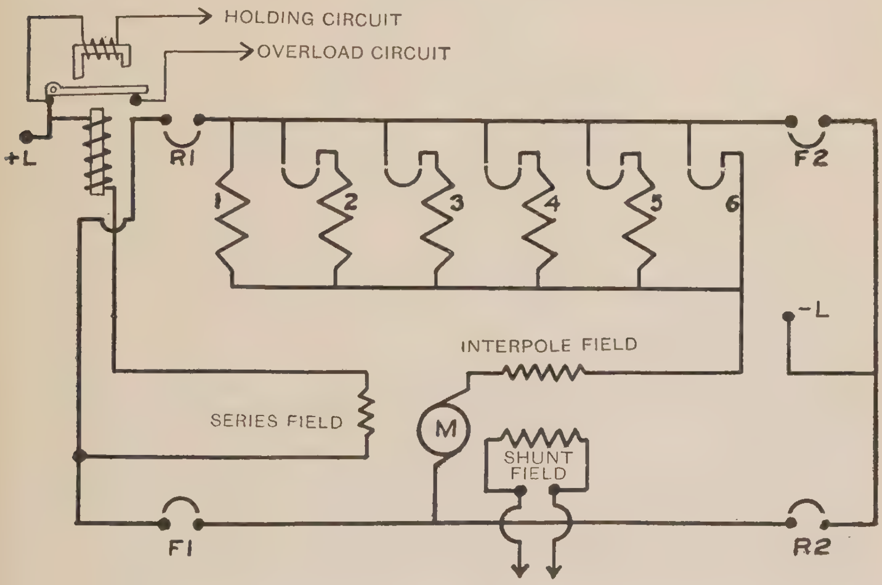


FIG. 299.—Elementary Diagram of Main Motor Contactor Panel.

To Stop.—The master is moved to the "off" position, allowing all clapper switches and contactors to open.

To Back.—The operator moves the master controller to the first backing position. This closes the pilot circuits of the line contactors R1 and R2 which close, feeding current to the motor through resistance 1, reversing current through armature and interpoles, but not through the series field. The starting resistance is then cut out as in going ahead.

Overload.—The current that energizes the pilot circuits flows to the master controller across the overload bridge, shown in the upper left-hand corner of Fig. 299. In case excessive current flows in the armature circuit, the armature of the overload magnet opens the bridge and all pilot circuits are broken, stopping the motor. The bridge is held open by the holding magnet which is not strong enough to raise it but will support its weight when opened by the overload coil. The circuit of the holding magnet is completed through the master controller when the latter is in any running position and will, therefore, prevent starting the motor until the controller is moved to "stop," when the bridge is released and closes. The motor may then be started again in the usual manner.

Auxiliaries.

Motors.—The usual motor-driven auxiliaries on board submarines are: Anchor windlass, air, water and fuel pumps, steering gear, ventilating fans, and motor generators for gyro compass. Of these only the steering motor circuits are unusual.

Steering Gear.—For both horizontal and vertical rudders shunt motors are provided. These are controlled by automatic contactor panels with pilot circuits leading to master controllers of some kind, the usual type being a small portable case carrying two watertight switches operated by push buttons. For the vertical rudder, pressing one push button energizes the line contactors and causes the motor to turn the rudder to the right. Starting resistance is automatically cut out but the rudder continues to move only as long as the push button is held down, there being no follow-up device provided. When the rudder reaches its extreme position a mechanical device opens the pilot circuit to that push button and stops the motor. The "left" push button may then be depressed and the rudder will continue to move to the left until the button is released or the limit cut out breaks the pilot circuit.

Cooking and Heating Appliances.—These are of the usual type and all are connected to the auxiliary switchboard, except the electric evaporator which has been supplied to some vessels. This has a heating coil wound for about 240 volts, connected directly across the motor terminals. It consumes too much current to operate from the storage batteries and is used only when cruising on the surface, being supplied directly from the dynamos.

Lighting System.—The lighting system is taken from the auxiliary switchboard and provision is made for supplying the lamps at their rated voltage by introducing a **dimmer** in the line. A dimmer is an ordinary rheostat used in a lighting circuit and is not automatic, being in construction similar to a field rheostat. Emergency lights are wired from the battery terminals or from power leads on the auxiliary switchboard and may be switched on if the regular lighting system fails.

Interior Communication.—The instruments and circuits used for interior communication in submarines are of the usual types.

Care of the Electrical Plant of Submarines.—The remarks regarding the care of electrical apparatus in general apply with particular force to the machinery of submarines, which is built with less than the usual margin of safety.

The storage batteries require careful and intelligent attention. The weight is scaled down to the lowest possible limit and they are very sensitive to improper treatment. One peculiarity of the storage battery is that it may be completely ruined without showing any immediate evidence of bad treatment, or giving any very definite clue as to the cause. For example, one cell may be continuously below normal specific gravity. The cause *may* be loss of electrolyte, but is more probably a short circuit in the cell or sulphation. In such case inexperience suggests the easiest apparent remedy, which is to add sulphuric acid to the electrolyte. The immediate result is normal cell readings, but in a short time the condition will again become abnormal, and examination will disclose plates sulphated beyond possibility of further use.

Another form of bad treatment is improper regulation of the ventilation. Knowing that insufficient ventilation is liable to cause explosion, the tendency is to run the blowers at the maximum speed at all times. This causes useless evaporation in the cells and requires that water be added to the electrolyte more frequently than necessary. Every effort is made to supply pure water, but impurities are always present, and always have a harmful effect on the plates. Consequently, whenever water is added unnecessarily, the life of the battery is shortened uselessly.

External short circuits are very destructive; the internal resistance is very small and the short circuit current is enormous and causes severe strains in the plates.

A frequent source of damage arises from errors in interpreting the information given by the various instruments used to indicate the condition of the cells. For example, two plates in a cell may have completely disintegrated, but shreds of paste clinging to the grids may still be active and at the end of a charge will register normal E. M. F. on a voltmeter; and the true condition of the cell can be determined only by considering voltmeter readings taken at intervals throughout the cycle of a charge and discharge.

Since the first indication of trouble in a cell is variation from normal voltage or gravity, it is obviously necessary that normal conditions be known. Therefore, it is essential that accurate records be kept of all tests made on each cell, and that these records be frequently referred to, in order that any deviation from normal may be detected in time to remove the cause before extensive damage is done.

The examples given here are a bare outline of the many factors entering into the care of accumulators. Comprehensive directions are furnished to all officers intrusted with the care of storage batteries, and these should be thoroughly studied and carefully followed. The tests and inspections required are often laborious, the necessity for some of them is not always obvious to the inexperienced, and there is a tendency to neglect the details when the omission of some test is not followed immediately by *apparent* harm. It should be borne in mind that submarine storage batteries are very expensive, and that repairs take much time, during which the vessel is of no military value. Neglect to learn how to care for the batteries, or neglect to properly care for them, or the delegation of this duty to an unqualified subordinate is inexcusable.

CHAPTER XXIII.

CARE AND MANAGEMENT OF ELECTRIC PLANT AND ACCESSORIES.

The first requisite in the care of electric machinery is cleanliness, and this refers not only to the engines and generators, but to all parts of the electric installation. The general appearance of a dynamo room and its appurtenances will be an index to the care given to the machines themselves. It is usually found that the engines of generating sets are a source of more trouble than the generators, mechanical faults being more persistent and more apt to occur than electrical ones, therefore the men detailed to operate the generating sets should have a thorough working knowledge of the engines and their auxiliaries, as well as of the generators.

Instructions and drawings are furnished to ships in the service, which give complete detailed data of each part of the electric plant and equipment, outlining the methods of assembling and disassembling the various parts, and with detailed instructions as to care and management. These instructions should be studied and carefully followed.

In order to keep the electrical installation in good condition, defects must be remedied as soon as discovered, and inspections and tests must be provided so that defects of any character cannot continue without detection.

Conditions as to economy and efficiency of operation can only be improved if accurate information is obtained as to actual performance. For this reason accurate records of performance should be made and retained for study, and frequent tests of the efficiency of apparatus should be made and compared.

Care of Dynamo Room.

The old rule, "A place for everything and everything in its place," is particularly applicable to ship's dynamo rooms. Tools, supplies, and spare parts should all be stowed in the places provided, and not be left about the dynamo room or near the machinery.

Cotton waste should be kept in the tanks provided. Oily waste should be kept in its own receptacle, which should be emptied at least once a day.

All paint work in the dynamo room should be kept scrupulously clean, and all metal bright work should have a high polish and be kept free of oil or moisture. The floor should be swept clean each watch, and be scrubbed at times with lye water. With care and a little attention, the dynamo room should be made one of the cleanest parts of the ship.

Excessive condensation occurs in the dynamo rooms when the engines are started after everything has become cold, and when such a condition is found to exist, the moisture must be removed from the apparatus by careful wiping. The generators should be operated without load until the moisture has been thrown off by centrifugal force, or evaporated by the heat of the engine and its auxiliaries.

The men on watch should be thoroughly familiar with the methods to be followed in handling the switchboard appliances in each of the different cases that arise. The sequence of operations should be standardized for each case according to the requirements of each particular plant, and rigidly adhered to.

A routine of inspections and overhauling should be established which should include all the electrical apparatus inside and outside the dynamo rooms.

Care and Management of Generators.

A good grade of light oil should be used in the bearings, and great care must be exercised to insure that the oil is free of foreign matter, that the oil rings function properly, and that the bearing heat never rises above the normal running heat.

The means of shifting the brushes, relative to the neutral points, must be kept free of paint or rust, so that they will work freely when necessity arises to shift brushes. In many cases brush rigging has been found to be frozen so badly due to paint or rust, that it was not possible to change the brush setting without extensive overhauling.

Any smell of burnt insulation or paint should be investigated immediately, and the cause rectified before operating the generator again.

The generator should operate without excessive vibration, commutation should be "black," or sparkless and the windings, commutator, brushes, and connections should not heat above normal.

Commutators.—As the commutator of a continuous-current machine is its most vital part, it should receive intelligent care when not running, and should be constantly watched when running, for under certain circumstances a few bad minutes may be sufficient to ruin it.

The commutator of modern well-designed generators should acquire with proper care a beautiful dark-bronze polished surface. This should not be taken as an indication of dirt that should be removed for it indicates a better condition than a clean, bright, highly polished commutator which may mean too much use of the file or sandpaper.

Local blackening indicates that sparking has occurred, due to one or more loose or high bars. It should be corrected by setting up on the nuts of the clamp ring bolts. Uniform blackening of the commutator is caused by sparking due to a generally poor surface, and should be corrected by grinding the commutator to a true surface.

High mica is easily identified, as the commutator surface will look raw all over instead of being smooth and bright with a dark-bronze gloss. This should be rectified by slotting the commutator, under-cutting the mica to a depth of not more than 1/16″.

If the commutator has been allowed to get rough or burnt at the leaving edges, it may be necessary to smooth it down with a fine mill file, but this should be done by an expert, for in inexperienced hands it is more likely to produce harm than good. A true cylindrical surface must be retained. Fine sandpaper fitted on a block shaped to the curve of the commutator can be used for finishing any rough places left by the file. Never use emery of any kind, as the particles of emery are good conductors, and may lodge between commutator bars and bridge them over. If emery is used it is practically impossible to remove all the emery dust, and the dust will work into the commutator, and continual wear on commutator and brushes will result.

If the commutator becomes so badly worn or scarred that sparking is persistent, it is better to place the armature in a lathe and grind the commutator true. After grinding, the commutator should be finished with fine sandpaper, and any particles of copper which may have lodged between the bars removed. In order to keep the armature windings free of the copper dust due to the grinding process, they should be carefully wrapped with cloth before grinding.

The commutator should not be oiled. If oil is used it is apt to char under the brushes, forming a film of carbonized oil between the commutator bars, causing more or less of a short circuit. Flying particles of copper or carbon from the commutator bars or brushes will stick to this film, increasing the short circuit. Never put oil where it is not required and make sure if handling oil that none gets on the commutator. Some of the armatures in the service have two armature windings, each connected to a separate commutator, but mounted on the same shaft; especial attention must be paid to these commutators, keeping both of them exceptionally free of oil or grease, as greasy commutators will cause an unequal distribution of load in the two armature windings, which may result in burning out one of the windings due to overload. An unbalanced load of as high as 300 amperes has been corrected by merely wiping the commutators with a piece of clean canvas.

A slight amount of lubrication is beneficial at times, and a good method of applying it is as follows: Provide a strip of canvas about the width of the commutator, and put a little vaseline on one side, smearing it with the finger all the way across, then when the machine is running press the vaselined side of the canvas against the commutator, holding it there until sufficiently lubricated; the commutator may be freed of dust, grease, or any kind of deposit that may lodge on it, in the same manner, using a coarser grade of canvas without lubricant.

Brushes must be so set that the pressure is not sufficient to gouge or score the commutator, while making such good contact that sparking will not result.

While running the commutator must be watched to prevent sparking at the brushes. This fault has been reduced to a minimum in recent machines, the brushes requiring no change from no load to full load, but it should be kept constantly in mind and watched for; signs of sparking in recent machines may mean something more than injury to the commutator.

Brush Rigging.—The brush holders should be thoroughly cleaned whenever the brushes tend to bind in them due to grease and dust accumulations, and the studs on which the brush holders are mounted should be kept in perfect alignment with the shaft; improper alignment of these studs is a common cause of sparking.

In brush holders of the adjustable type the exact position of the ring or yoke, as determined and marked at the time of installation, should always be maintained thereafter, unless the machine must be operated under heavy sustained overloads, under which condition the ring or yoke should be reset to prevent sparking due to abnormal load.

The studs carrying the brush holders are insulated from their supports by insulating bushings and collars, the assembly being held in place by nuts; these nuts may work loose after having been properly set up, allowing the studs to turn and lift the brushes from the commutator. Frequent inspection is necessary to insure the tightness of the nuts.

Brushes.—The proper position of brushes depends upon the particular winding, internal connections, cross-connections, etc., and it should never be assumed that the proper position is known, but the directions furnished by the makers should be followed.

In many of the four-pole generators used in the service, the armature is cross-connected, necessitating but one set of brushes set 90 degrees apart, the neutral position being between the poles. In a later design of six-pole machine there are three sets of brushes set 120 degrees apart and under the poles, the armature not being cross-connected. The three positive and three negative brushes are connected in multiple. In this machine there is a reference mark on the pedestal and one in the brush-holder yoke, and when they are in line, the brushes are in the right position. If the brushes are in the exactly opposite position to the proper one, the machine will not build up at all, but a little experimenting will serve to show the correct position.

Of whatever material brushes are made they should rest evenly on the commutator with a uniform pressure of about 1½ pounds per square inch of bearing surface, additional pressure merely increasing friction, causing excessive wear of commutator and brushes. Large brushes on the bottom of a commutator require a heavier spring tension than those on top of the commutator to give the same pressure on the commutator. The pressure may be measured by using a small spring balance carrying a flat hook. The hook should be slipped between the center of the brush and the commutator, and the brush then pulled directly away from the commutator until it just leaves the commutator. The pressure is indicated by the reading of the balance. Care must be taken to insure that the brush does not bind in the box of the brush holder.

Carbon brushes are fitted to the commutator by passing fine sandpaper beneath them, the sanded side to face the brushes, and drawing the sandpaper between the commutator and the brushes, taking care that the sandpaper is made to conform to the curvature of the commutator. Each time the sandpaper is drawn back to the starting point the brushes should be raised, or the results will be unsatisfactory. Another method of fitting carbon brushes is to cover the entire surface of the commutator with sandpaper, pasting it on, and being careful not to have the sheets of sandpaper overlap. Then revolve the armature until the brushes are well fitted. If the brushes require considerable fitting, No. 2 sandpaper may be used at first, but the final fitting should be done with No. 0 sandpaper. When fitting brushes with sandpaper, do not press down with the hand, but utilize the pressure of the brush-holder spring, because if the hand is used, the brush may be forced to take a different position from that derived from the spring pressure and consequently not be fitted to the commutator properly when the machine is running. In addition to following the above instructions the machine should be run as long as convenient without load in order to improve their surfaces.

If the brushes are made of copper (the slip rings of the three-wire generators used in latest installations are equipped with copper brushes) they are fitted so as to make an angle with the normal to the commutator. This necessitates the ends being filed to the proper angle, and this is usually accomplished by placing them in a jig, a metal box mitered at one end to the angle desired, and filing the brushes in agreement. After being filed down the copper brushes are set in their holders, and soon smooth down when in operation, as the commutator is harder than the brushes.

Carbon brushes require less attention than those made of copper; they do not cut the commutator as much, and their higher resistance assists commutation, but this same added resistance causes them to heat more under the same load conditions, therefore they must be made larger.

Brushes should be "staggered" to cover as much of the commutator surface as possible, and they should be reset at times in the direction of the length of the bars if there are insufficient brushes to fully cover the commutator. Some makers core the carbon brushes with a graphite compound, as a means of lubricating the commutator, thereby decreasing the wear on it and increasing the life of the brushes.

Windings.—The **field windings** rarely give trouble, but their life may be prolonged by carefully wiping off any oil thrown on them from the engine, and keeping them free of foreign matter. Especial attention should be paid to the air ducts. The connections should be examined from time to time to see that they are tight, and not liable to contact with the magnet frame. In some instances the lower field coil has been injured by being saturated with water or oil, or both, due to leakage from the engine to the pocket formed by the interior of the generator base. This pocket should be kept absolutely clean and dry.

The **armature windings**, especially those of turbo-generators, should receive regular and conscientious attention, to avoid accumulations of oil and foreign matter which would either rot the insulation, clog the air ducts, or otherwise interfere with the designed means for efficiently radiating the heat generated in them. Loose pieces of insulation or stray ends of tape should be removed or properly anchored; the centrifugal force generated in these loose particles at operating speeds is sufficient to throw them off at times, with the possibility of serious damage. The binding wires must be firmly anchored, and there must be sufficient clearance between them and the pole pieces to prevent rubbing. If a binding wire does get adrift, do not assume that the remaining binding wires are sufficient to keep the windings in place, but replace it before operating the generator again. The ampere rating of the generator, indicated by its name-plate data, should not be exceeded, as otherwise the windings will be heated beyond the designed limits, and the insulation weakened, not to mention the bad effects on the commutator and brushes. Insulation tests should be made periodically to ascertain faulty insulation due to moisture or any of the above-noted faults, and if the insulation proves to be low the cause should be determined and corrected before attempting to operate again under load.

Care of Steam Auxiliaries.

The manifolds, valves, and flanges of the piping system should be kept free of leaks; defects should be remedied as soon as possible after they are discovered.

When the piping system is warmed up prior to starting up the plant, great care should be taken to warm up gradually and evenly, as sudden temperature strains will surely cause damage to the piping and to the pipe fittings. See that all pipe lagging is intact; very often the lagging is injured when machinery is being overhauled, in which case it should be repaired without delay to prevent loss in efficiency by radiation of heat.

Pressure gauges should be calibrated whenever opportunity presents itself. **Reducing valves** should actually reduce the pressure as intended. **Separators** require very little attention, but it is a good plan to see that their connections to the traps are not restricted by scale or other deposits. The dumping arrangements of the **traps** will require occasional overhaul to keep them working freely, and it is imperative that the drainage lines from the traps to the gravity tanks, hot-wells, or feed tanks are not choked, are as direct as possible, and are sufficiently large to drain the traps quickly.

If fitted with an automatic **atmospheric exhaust valve**, it should be operated at intervals, as a test.

The **condensing plant** should receive continual attention. High vacuum is a necessity with turbines, and the plant is not operating efficiently unless it is maintained. The circulating pump must be run at a speed which will keep the condenser from heating, and the air pump must keep the condenser free of water. When machines are started up or shut down, the speed of the air and circulating pumps will have to be adjusted to meet the conditions.

Causes of low vacuum must be searched for, and remedied as soon as possible after they are located.

The condenser should be boiled out occasionally, using the connections provided for the purpose, and periodically it should be tested and carefully inspected for leaks. The condensed water should be tested daily for salinity; if the water is salty the cause is probably a leaky condenser. The condenser must be tested. Leaky tubes should be replaced, or plugged, and ferrules set up or packing renewed.

There is a tendency for the sea suction and discharge connections of the circulating system, especially the suction, to become clogged with marine growth, sand, mud, or the silt from ashes ejected from the ship, and they should be blown out often by means of the steam connection provided as a preventive, especially when the ship is in shoal waters, as when moored to a dock. If either of these connections should become so badly clogged that they cannot be freed by application of a reasonable steam pressure, the plant should be operated non-condensing, and the condensing plant shut down; the trouble should then be rectified by divers. Cases are on record in the service of sea connections which were allowed to clog up so badly that when a full head of steam was applied to clear them, the castings were ruptured.

Occasionally the gravity tanks and the hot-wells should be thoroughly cleaned, the filtering material of the latter being renewed as required.

The engine end of the pumps require the same general care as reciprocating engines, which subject is discussed below. Special attention should be paid to the water ends of the pumps, as the valves require reseating and renewal at regular intervals, and the zincs will require renewal.

The attendants in the dynamo room should thoroughly understand the use and location of every steam auxiliary, and all piping and valves, and be prepared to meet emergencies quickly. Every fault which may arise should be thoroughly understood, and the methods of meeting them studied in advance, as the failure of auxiliaries may cause the plant to be shut down, putting the ship in darkness, and stopping all motor-driven apparatus.

Care of Reciprocating Engines.

In this, as in all other parts of the electric installation, the first requisite is cleanliness. All parts of the bright work should be kept bright and polished, free from oil and grease except where needed, and the paint work clean and free from dirt and grease spots.

It is well to establish a routine for the overhauling of the engine parts, and not assume that because everything is working well, it is going to do so forever without care and time spent on it. The bearings and journals should be examined regularly, the caps removed and bearing linings examined and adjusted. The oil feeders should be removed occasionally and thoroughly cleaned out, as they are apt to clog after constant use.

The piston-rod and valve-rod packings should be constantly watched, and if steam leaks develop the packings should be cleaned, scraped, or renewed as required. An overheated, scored, or leaded rod will ruin its packing very quickly. The cylinder heads should be taken off monthly, and the pistons and inside of the cylinders examined. The cylinders should be given a light coating of a mixture of vaseline and plumbago for lubrication, oil not being used in the steam spaces except under special circumstances.

It is well not to touch the governor as long as it is performing well, for this is a most important piece of mechanism, and overhauling is more likely to do harm than good. When it fails, the remedy should be sought and applied, particular attention being given to the tension of the spring.

The drain and relief valves should be occasionally unscrewed, the valve seats inspected, regrinding if required; the springs of the relief valves should be free from scale, and in condition to function properly.

Particular attention should be given to any noise or knocks that may develop when the engine is running; every noise is caused by a particular defect, and the defect should be remedied as soon as possible. Lost motion is the most common cause of knocking, and it should be remedied by setting up on the loose parts, or by refitting them.

In simple engines, the valves should be so set that each cylinder is doing an equal amount of work, and in compound engines that the two cylinders are each doing their proportionate share. This can only be ascertained by taking indicator cards, which should be done frequently and the horsepower of each cylinder calculated. Besides the power developed the cards will also show whether the valves are set properly, and the general compounding of the engines. Cards should be taken at different loads on the generator and the voltage and current noted at the same time, in order that the net efficiency of the set may be determined.

While the engine is running, it is imperative that lubrication be thorough, the cylinders free of water, and the governor functioning properly, and if undue vibration or noises develop the engine should be stopped immediately, and the cause investigated. In the event of hot bearings developing, remove the load, reduce the speed of the engine, and use all available means to cool the bearing before stopping the engine, as otherwise the bearing linings may freeze to the journal.

A full set of wrenches, spanners, and special tools is supplied with each engine, each tool having its particular use, and should be used for that purpose and no other.

Care of Turbine Engines.

The remarks under the heading "**Care of Reciprocating Engines**" referring to cleanliness and establishing routine for overhauling the engine apply equally well to turbine engines.

The bearings and journals should be examined regularly, the caps removed, and bearing linings examined and adjusted.

The lubricating system must be maintained in highly efficient condition, due to the high operating speed of the turbine; see that sufficient pressure is maintained on the cooling system to keep the oil from heating abnormally. The oil should be filtered occasionally and mixed with new oil, the frequency depending upon the oil used, and the number of hours the turbine has been in operation; use pure mineral hydro-carbon oil that is free of acids, saponifiable matter, and water, having a specific gravity of between 0.860 and 0.880 at 60 degrees Fahrenheit. Be careful to keep oil from the carbon packings of the seal glands, as it will carbonize on the packings and prevent their proper alignment on the shaft.

The axial clearance between the first-stage nozzles and the shroud band of the first row of buckets WHEN THE TURBINE IS COLD is usually given in the instructions furnished by the maker; it can be adjusted by interchanging U-shaped shims on the ends of the bearing linings.

See that the balance of the parts is preserved; vibration may be caused by faulty alignment, defects in foundation, excessive wear of the bearing linings, by erosion of portions of the rotor, or by incrustations of non-uniform deposits. If vibration is due to an unbalanced rotor, and is of a minor nature, it may be corrected by inserting or relocating balance plugs in the outer commutator shrink rings, which are tapped for this purpose, taking care that the plugs are well anchored; if the rotor is unbalanced to any great extent, it may be rectified by mounting alloy balance strips on the wheel ring, fitted to the contour of the rings, and so mounted that their weight will be taken by the wheel ring and not by the screws.

See that the governor gear is kept intact, and that all of its parts are efficiently lubricated. From time to time the setting of the governor should be checked up by means of the trams provided at the time of installation.

See that the drains for the seal glands are effective. About once in six months the screen of the steam strainer should be cleaned, renewing it if it is found to be damaged due to foreign matter in the steam line.

While the turbine is running, it is imperative that the casings be kept free of water, that lubrication is thorough, that the governor is functioning properly, that the turbine is operating without undue vibration, and that the emergency devices are in efficient operating condition.

Operation of the Set.

Before Starting.—The engine and generator should be subjected to a rigid inspection to insure that all connections, nuts, studs, bolts, and screws are tight, packing glands set up snugly, no binding wires loose, and that the engine and generator are free of tools, parts, and anything that might interfere with the operation.

See circuit breaker and switches open.

See that the commutator is clean and dry.

Turn the engine over by hand once or twice to make certain that no parts are binding, and nothing foul of the moving parts.

See the condensing plant operating satisfactorily.

Inspect the lubricating apparatus. Clean oil strainers. Fill oil reservoirs to proper level, draining off any water.

Put a few drops of oil on all moving parts of the governor gear, controlling valves, and all other moving parts which might require oiling and are not fitted with means of lubrication while in operation.

To Start. RECIPROCATING ENGINE SETS.—Assuming that all of the precautions noted above have been taken, the set should be ready to be started at an instant's notice, the only time required being that necessary to warm up the engine gradually and evenly, and to free the cylinders of water.

Open the cylinder drains (if not open) and receiver drains.

Fully open exhaust valve, and engine stop valve.

Crack the throttle valve slightly, allowing steam to enter the valve chests and cylinders, and turn the engine over once or twice by hand to allow the steam to take its full course and warm all parts, stopping so as to bring the piston just past the top center, in the direction of rotation. If the engine is compound, open the by-pass valve.

When the cylinders are fully heated, condensation will cease, and the engine will usually start without further opening of the throttle valve; if not, open the throttle valve slowly until it does start, then close it to a point that will just prevent stopping the engine.

Check up the operation of the lubricating system, and make certain that none of the engine parts are heating abnormally.

When the cylinders are free of water, open the throttle valve slowly, bringing the engine to full speed. After running at full speed a few minutes, close drains and by-pass. In case of water in cylinders thereafter, open drains, and by-pass, and, if necessary, slow the engine until free of water, then bring to full speed again.

TURBO-GENERATOR SETS.—Open the valves on water circulation system for main bearings, and see water running through the system freely.

Open both casing and both seal gland drain valves. (Care should be exercised not to keep the first stage casing drain open longer than is required to drain the casing, as there is an average of about 14 pounds pressure in the first stage casing, which would cause unnecessary heating of the condenser, with resultant loss in vacuum.)

Turn steam on seal glands, throttling the valve until a very slight steam vapor leaks to atmosphere from the glands. The applied pressure should never exceed 12 pounds.

Fully open exhaust valve on turbine, and see that main exhaust valve on condenser is wide open.

Crack throttle valve very slightly, admitting just enough steam to the turbine to warm it and its pipe connections to the condenser, evenly and gradually.

When the turbine casings are fully heated, condensation will cease in the casings, and the rotor will usually start turning without further opening of the throttle valve. If the rotor does not start promptly, when the casings are fully heated, open the throttle valve by very small increments until it does start. Then close the throttle quickly to a point just sufficient to prevent stopping the rotor. The rotor will accelerate to full speed with very small steam consumption in a short time, and then the throttle valve should be opened wide.

As soon as the rotor is in motion, check up the oil circulation for the bearings. The oil pressure should be not less than four pounds and not more than twelve pounds. See that the oil rings are turning in the bearings, distributing oil on the shaft freely.

If the turbine vibrates while starting up, or while in operation, it may be out of balance, but this is usually an indication that the casings are not free of water, due to wet steam or to improper drainage. It is the usual practice to leave the casing drain valves cracked slightly while the turbine is in operation, as a precaution against water hammer, this practice being governed by local conditions.

When the casings are free of water, are fully heated, and the rotor is turning free of vibration, the casing drain valves may be closed. No hard and fast rule can be given as to when to close the casing drains, as it depends on local conditions, particularly the quality of the steam supplied.

Close the seal gland drains, and readjust steam pressure on the glands. Readjust condenser plant to meet the change in load conditions.

The operation with the generator is the same as with that of the generator of the reciprocating engine set.

If a speed in excess of 8 per cent above normal is attained while starting, or when in operation, or if, due to back pressure, a pressure of 10 pounds exists in the exhaust stage, the throttle valve will be closed automatically by means of SPEED LIMITING DEVICE, or the BACK-PRESSURE EMERGENCY TRIPPING DEVICE, respectively, meeting the emergencies by shutting down the turbine.

If the sentinel valve "pops" while starting up, or when in operation, it indicates that an excessive pressure exists in the exhaust stage, and that the tripping device has failed to act, and THE TURBINE SHOULD BE STOPPED IMMEDIATELY by means of the hand tripping device.

GENERATOR: *Operating Singly.*—As the generator builds up, the voltage is indicated by the glowing of the pilot lamp and by the voltmeter, and should be regulated by the shunt field rheostat, bringing it to the line voltage. Then close circuit breaker. Close negative switch. Close positive lighting, power, or both, as desired.

To Connect in Parallel.—Bring voltage of No. 2 to that of No. 1, already in operation, by means of the shunt field rheostat.

Close circuit breaker.

Close equalizer switch of **both** machines.

Close common negative switch.

Adjust voltage of No. 1 to line voltage, if it falls off.

Bring voltage of No. 2 to No. 1, checking by calibrating voltmeter.

Close positive lighting switch, power switch, or both.

Adjust the loads between the machines, keeping the voltage constant.

To Stop. RECIPROCATING ENGINE SETS.—Reduce the load by means of the field rheostat, then trip the circuit breakers of the generator to be stopped. Open the main switches of that generator to the switchboard.

Close throttle valve gradually, then close the engine stop valve; open the drains fully, and when the engine is at a stand still, close the exhaust valve, and shut off the oil supply.

TURBO-GENERATOR SETS.—The operation with the generator is the same as described above.

Stop the turbine by means of the hand tripping device.

Close seal gland valve.

Close exhaust when the turbine is at a stand still, and readjust condensing plant to the new load conditions.

Open seal gland drain valves, and leave them open while the turbine is shut down.

If casing drain valves were cracked, close them.

After Stopping.—All machines should be cleaned at once, all repairs and adjustments that may be required should be made as soon as possible, and the set prepared for starting.

The engine and generator should be cleaned; oil should be wiped off the engine and its parts, and off all parts of the generator.

GENERATORS.—The armature and commutator, and such other parts as may be considered necessary, should be blown out with compressed air or with hand bellows. Care must be taken to remove all foreign substance from armature conductors where they are connected to commutator bars. Undercut spaces between commutator bars must be thoroughly cleaned down to the mica insulation. Grit, dust, and grease must be wiped off and care taken that no pieces of waste are left sticking to any part, moving or stationary.

The brushes should be lifted and examined to see that they do not tend to stick in the brush holders, that they have worn evenly, and that they are resting on the commutator with the requisite pressure.

Every part of the armature should be examined and it should be turned over by hand to see that there have been no abrasions of the windings, or evidence of the armature striking the pole pieces.

The commutator should be examined for any sign of wearing, cutting, or other damage, and the insulation examined to see if there is a tendency to rise.

All connections should be looked at and loose ones tightened. Circuit breakers should be examined, and their working parts tested.

RECIPROCATING ENGINES.—All defects existing while running should have been noted and all should now be remedied. The engine should be cleaned, leaky rod or valve-stem packing should be examined and refitted, or renewed. Loose bearings or bearings that have heated should be examined, and refitted.

TURBINES.—As with reciprocating engines, this is the time to repair any defects noted while the engine was running. The turbine should first be cleaned thoroughly, and all nuts, bolts, screws, and parts that might work loose examined and set up. Valve springs should be inspected, as should valve stems and packing, and repairs made promptly where needed.

The machine should then be made ready for operation; see first controlling valve *open*. Replenish oil in reservoirs and clean oil strainers.

Care of Switchboards and Switchboard Appliances.

The handling of the switchboard appliances should be standardized; undoubtedly some of the switching operations may be handled in different sequences, but interruption of service due to improper manipulation of the switchboard will be eliminated to a considerable extent, if each operation is standardized, and one method rigidly adhered to.

Switchboards should be cleaned daily and kept free from grease and dust. The panels and the instruments should be freed of dust and given a high polish with a piece of clean dry chamois which is not to be used for any other purpose. If greasy deposits do collect on the switchboards they should be removed with a clean rag, free of lint, which has been moistened with alcohol, or in the absence of alcohol, with turpentine or turpentine substitute. The glasses of the instruments should be cleaned in the same way.

All metal portions of the switchboards should be carefully cleaned, taking care that the cleaning process does not remove the lacquer finish.

The back of the switchboards should be thoroughly dusted at least once a week, and all connections tightened up very carefully, using well-insulated tools, and being careful not to create grounds, crosses, or short circuits, or to strip any of the threads.

No change in any of the switchboard connections should ever be permitted without instructions from the officer-in-charge. The component parts of the switchboard should be kept free of electrical defects, and not overloaded.

Switches.—Blisters and burns should be removed from switches as soon as they are detected, as they cause imperfect contact when the switches are closed. If not visible they are detected by abnormal heating of the switches.

The joints of the knife switches should be sufficiently tight to hold the blade in any position in which it is placed, but not so tight that they cannot be opened or closed promptly and without any great effort.

Circuit switches should be opened and closed smartly, to prevent arcs being formed which would injure them, being fully seated in the clips when closed and well away from the clips when open.

Never open a field switch which is energized if it can be avoided, as there is a possibility of rupturing the insulation of the field coils due to the inductive discharge of the circuit. Certain field switches which must be opened are equipped with field discharge resistance to take care of the inductive discharge. Some switches are provided with insulated guards for the clips of the switches, as a precaution against improper switching; care must be exercised that these guards are not misplaced or lost, and that they are used as intended.

Fuses.—Lists giving data of the proper size fuses for each circuit on the switchboards should be posted in the bulletin boards of the dynamo room and distribution rooms, and these lists should be rigidly adhered to. If fuses blow frequently and the circuits they protect are free of grounds or short circuits, it will usually be found that some of the apparatus on the circuit is overloaded. This may be caused by additional unauthorized outlets.

When replacing fuses, always open the switch controlling the circuit the fuses protect; stand on insulating material, do not touch grounded metal, and use insulated tools where possible. A slight shock might cause the dropping of a tool that might cause short circuits. Do not allow the screws holding a fuse to fall, as they are liable to lodge in some place where they might cause a short circuit.

When replacing link fuses, set up on one end lightly, keeping the other end pointed away from its contact, then swing the free end to its contact and set up snugly on both screws, being extremely careful that the fuses do not make contact with parts of adjacent switches, causing short circuits.

Cartridge fuses are replaced in the same manner as link fuses if they are made up with link ends; some types of cartridge fuses are made up so as to be inserted in switch clips in the same manner as switch blades, this latter type being replaced very quickly when blown.

When replacing branch fuses, care should be taken not to stretch the fuse wire in the tube, thereby decreasing the capacity of the fuse. They should be replaced by entering one end of the fuse into its clips as far as it will go, the other end then being forced into the other clips with a piece of wood or other convenient insulating material (to avoid possibility of a shock). The glass tube will probably be broken if an attempt is made to enter both ends of the fuse into their clips at the same time, as the junction box fuse clips are made very stiff in order to eliminate possibility of poor contact.

If equipped with fuse guards, see that they are not misplaced or lost, and that they are used as intended.

Circuit Breakers.—The circuit breakers should be cleaned daily, inspected at least once a month for signs of deterioration, and be tested semi-annually under overload conditions.

The adjustment of the laminated contacts should be such that the circuit breakers can be closed without excess effort, and without spreading the laminations to a point where they receive a permanent set. The auxiliary or secondary contacts should be so adjusted that they make circuit *before,* and break circuit *after* the main contacts, in order that all arcing may be borne by the secondary contacts, which are renewable. This adjustment is determined by the type and size of the circuit breaker.

The surface of the contacts must be free of blisters or burns, to allow of perfect contact. It is a good practice to test the heating of the circuit breaker and its connections occasionally under load conditions, by placing the hand on the parts, taking care to stand on insulating material, and to keep the other hand away from live parts of the apparatus. Undue heating should be investigated and remedied.

Tripping, holding, and magnetic blowout coils, and the general insulation of the circuit breaker should be kept free of oil, and tested frequently.

If arc chutes are fitted, see that they are intact, as they are usually made of asbestos press board, which may crack or flake off due to injury received in service.

If time limits are fitted, the dash-pot arrangements will require occasional cleaning and renewal of fluid.

Instruments.—The instruments should be kept scrupulously clean, and the glasses highly polished. The major points to be considered are: that they are operated within their prescribed limits, are not subjected to jars or vibration, are absolutely free from moisture, and that all connections are tight and electrically clean.

Those provided with switching arrangements should be kept out of circuit except when actually reading them, unless they are of the recording type, as continual usage tends to cause a permanent set and a corresponding error in the readings.

The seals of the meters should not be broken. Inspection will show instantly whether they have been tampered with. If instruments should get out of order, it is preferable, whenever possible, to substitute a spare, and have a defective instrument overhauled at the first opportunity by a man who has specialized at that class of work, as it is very delicate work requiring a high degree of skill.

At times meters that fail to function may be corrected by merely tapping the instrument case with the finger.

It is important that the non-inductive leads connecting ammeters to their respective shunts be kept as installed; leads have been shortened without authority by inexperienced men in order to make a neater job of wiring, which of course threw the ammeters out of calibration. The serial numbers of the ammeters and their shunts should be in agreement, as it sometimes happens that they get shifted around when a group of ammeters is replaced after having been overhauled.

The voltmeters being self-contained rarely give trouble, but they should be compared from time to time with the standard instrument mounted on the switchboard, any corrections noted being posted where they can be used as a guide by the switchboard attendants.

Lamp ground detectors should be left in circuit continuously, but the voltmeter ground detector should only be used while actually conducting a test.

If wattmeters are installed, their readings should be checked occasionally by comparison with the product of the instantaneous values of the voltmeter and ammeter readings.

Care of Circuits Outside the Dynamo Room.

The electrical appliances outside the dynamo rooms are numerous and widespread, and to supply them with electrical energy requires an elaborate system of wiring. A large force of men is required to maintain this equipment in efficient condition, and it can only be done by the enforcement of an exacting routine of inspections, tests, and overhauling which is thorough enough in its details to anticipate every possible fault in all parts of the installation. This routine should be based on past experience, the data furnished with the equipment, and the difficulties encountered daily.

The work of upkeep should be divided into distinct stations or units. The number of men and class of work assigned to each depends on the arrangement of the particular ship. The work assigned to each station should be definite and clearly understood.

The instructions and routines for each station should include all existing service regulations and instructions so far as they apply, and should divide the work evenly between the men of the electrical division.

Every man should be trained to inspect every portion of the installation in his care in accordance with a prescribed routine, correcting petty faults immediately, and notifying those in charge of the defects of a more serious nature.

No changes in connections or modification of any of the apparatus should be permitted except by order of the officer-in-charge, or in extreme emergencies.

Each circuit in the ship should be tested daily for grounds, the test being conducted at the main and distribution switchboards, the best time being between 4 and 6 a. m., as interruption of the circuits under test at that time will not interfere materially with the ship routine; defects noted during the ground test should be rectified without delay.

Advantage should be taken of mild weather to thoroughly overhaul all weather deck circuits, as it is a hard matter to do effective work on them in cold or squally weather.

The greatest single cause of the breakdown of wiring appliances is moisture, and this should be removed at once, wherever it appears, and guarded against by maintaining the watertightness of the appliances.

Water, dirt, improper handling of the apparatus, and carelessness are the major causes of trouble, as each part of the equipment was subjected to very rigid acceptance tests, both before and after installation, and when difficulties are experienced with apparatus, it is quite possible that the fault lies with the operator.

Wires and Cables.—Wires and cables should be kept free of water, moisture, oil, or grease, to prevent deterioration of their insulation, or injury to the wire itself due to oxidation or electrolysis.

The conductors should not be overloaded, as overloading is bound to injure the insulation, even though the wire itself may not be damaged.

The above precautions should be particularly observed with the wiring of very hot spaces, such as fire rooms, as the insulation deteriorates much more rapidly due to the great heat.

Great care should be taken to keep all wiring connections electrically clean and tight; wire ends should be laid up systematically in the wiring appliances, to facilitate testing and repairs, the spare wires in the system being used sparingly in order that some may be available when emergencies arise.

As a matter of sanitation and appearance, all portable wires and cables should be kept clean, and be given a coat of flexible black insulating paint from time to time. Chafed portions of the outer braid should be taped and served with small stuff to prevent further injury.

Wiring Appliances.—All wiring appliances should be kept watertight. This can be only effected by keeping all glands well packed, a full complement of screws in all box covers, the box covers set up snugly and their gaskets intact, all screw caps watertight. Screw caps of the appliances must be set up when not removed for inspection or for actual use of the appliance, and be tight enough for the gaskets to function. The means of retaining these caps should be efficient.

The original finish of the appliances should be preserved; if painted they will soon present an untidy appearance due to paint accumulations, making it difficult to remove the screws, and destroying the gaskets; if polished, there will be a tendency for the compartment cleaners to remove box covers, etc., resulting in damage to the appliances as a rule.

The interior fittings of the wiring appliances should be kept intact, firmly secured, and clean. Fuse boxes should be inspected periodically to see that they are properly fused, and are free of molten fuse metal. No one except the electrical force should be allowed to attempt minor repairs on their own responsibility, as this sometimes results in the use of heavy wire or nails to replace fuses, with consequently greater damage.

When moisture is detected in any of the wiring appliances, they should be thoroughly dried before the covers are replaced. Salt water is more to be avoided than fresh. It is a better conductor, augments electrolytic action, and in addition the salt deposited will absorb moisture from the air.

Fixtures.—All fixtures should be thoroughly cleaned at least once a week, glass shades, globes, and incandescent lamps being cleaned and polished. Clean, soft scrap paper is very handy and economical for polishing the glassware. Silver-plated or bronzed fixtures should be kept clean by wiping with a clean, soft rag slightly oiled, but the oil should be wiped dry; if polished the lacquer finish will be destroyed. The interior of the globes of steam-tight fixtures will rarely require cleaning if the gaskets are efficient and the globes are screwed up snugly, but if dirt does collect in them they should be thoroughly cleaned, making certain when replacing that the gaskets are in place and are pliable, and that the globes are screwed up snugly.

All fixtures should be intact, parts properly assembled and secured, and the original finish preserved. Fixtures should never be painted. If the finish has been neglected, the parts should be cleaned by scraping, dipped in a strong solution of muriatic and nitric acid in equal parts with a small amount of common salt added, then buffed, and lacquered while the parts retain the heat of the buffing process; if it is not convenient to buff certain parts due to construction, the buffing may be dispensed with, but they should be lacquered.

Special attention should be paid to portable fixtures, as they are subjected to severe usage; breakage of the tips of their attachment plugs may be reduced to a minimum, by enforcing a rule that when in use the plugs be made watertight and firmly anchored in the outlets by screwing up snugly on the locking rings of the plugs.

Care and Management of Motors.

The routine for the proper maintenance of the motor equipment should be strictly adhered to, special attention being paid to the commutators, brushes, bearings and lubricating systems, and their cleanliness. Each motor should be thoroughly cleaned at least once a week, the work of cleaning being distributed among several men as part of their regular work. Necessary repairs should be made by repair parties.

The commutators, brush rigging, and windings should receive the same general care as outlined under the headings "**Generators,**" as they are identical except in certain structural details. Due to the fact that there is a large number of motors and that they are distributed throughout the ship, it will be found impracticable with the force available, to constantly supervise every one that is in operation, as is the case with the generators, but whenever trouble is experienced with any of the motors, they should be watched constantly until they are operating satisfactorily.

A motor watch should be established and the men on that watch instructed to make tours of the ship, by prescribed routes, inspecting all motors which are in operation, rectifying minor defects immediately, defects of a more serious nature being remedied by the repair party; when the route has been fully covered, the same tour of inspection should be repeated, the watch being relieved every four hours; this man should be fully equipped to effect minor repairs, thereby eliminating delays caused by looking for store-room keepers, etc.

The motors inspected by this watch should include all motors which are not under the immediate supervision of the electricians detailed to operate them. This latter group depends on the ship's organization, but usually includes turret and ammunition-hoist motors. The ventilating blower motors will require the most attention, as they are in operation continuously. In hot weather the setting of the brushes should be carefully checked, as cases are on record of unauthorized persons (sometimes the electricians themselves) changing the brush setting by means of the adjustments provided, in order to speed up the blower motor, resulting in sparking, and overloading the motor. Machine-shop motors should be kept free of the metal turnings and chips common to such places.

Motors on weather decks should be tested more frequently than the rest of the motor equipment, as they are exposed to rain, salt-water spray, salt water from the wash-deck hose, the heat of the sun, and dirt which is blown on them. It is good practice to thoroughly ventilate them on warm, sunny days whenever practicable, by removing the access plates of the motors and operating them without load for a few minutes.

Turret and ammunition-hoist motors should be kept in flame-proof condition to avoid possibility of igniting combustible materials in the vicinity; special attention should be paid to the lubrication of this class of motors, as it is frequently neglected due to the fact that they are sometimes installed in inaccessible places.

When trouble is experienced with any of the motors, before breaking them down for overhaul check the load with the ammeter to insure that the trouble is not due to overload. The ammeter readings should not be in excess of the amperage marked on the name plate of the motor. The practice of speeding up motors by weakening the strength of their fields beyond the designed limits should not be allowed, as it lowers the starting torque of the motors, and overloads them, with the result that the life of the motors is bound to be shortened.

Bearings.—The bearings of the motors should be inspected regularly by the man on the motor watch. Under proper conditions, no reasonable excuse can be offered or accepted for abnormal heating of bearings. If it exists, it requires immediate investigation and remedy.

After being in operation a short time, a certain amount of heat is imparted to the bearings by the armature; any undue heating aside from this requires the immediate attention of the attendant. The temperature may reach blood heat when running fully loaded.

Undue heating may result from a variety of causes. Among these may be mentioned insufficient quantity or poor quality of lubricant, dirt or grit in oil or bearing, a badly adjusted bearing, rough journals, an armature shaft slightly bent, or bearings out of line.

If from any cause a bearing becomes unduly warm, a liberal supply of oil may be sufficient to check the heating. If it gets very hot, cold fresh oil will benefit it. It is not advisable to use water on the interior of the bearings unless sure that it is free from dust and grit, although in case of emergency, water or ice may be used upon the outside of the box of iron-clad motors, to reduce the temperature of the bearings.

If a hot bearing develops, the bearing cap should be slightly loosened, if the bearing has a split lining, and the speed of the shaft reduced slowly until the temperature has fallen to a safe limit. If the motor is stopped suddenly a sleeve bearing lining is liable to contract upon the shaft so tightly that it cannot be removed except by cutting it off, and the shaft may be injured.

The cause of the heating should always be ascertained and remedied, and the bearing cap removed, the bearing cleaned, scraped and accurately refitted before starting up again.

If the bearing cap or bearing linings are removed for purpose of overhaul, when replaced the bearing surfaces and dowel pins must be free from grit, fibers of waste, or other forms of foreign matter.

If the bearings should become considerably worn, there is danger that the armature of the motor may rub upon the pole pieces. By observing the air-gaps closely, it may be readily seen whether the bearings are worn down to any considerable extent, in which case the bearing linings should be renewed.

The oil or grease used in the bearing should be free of foreign matter and new oil should be strained. The oil in self-oiling bearings should be kept at the proper height by replenishing as required, renewing it every three or four months, or whenever it appears that the quality of the lubricant has deteriorated, making certain that the oil well has been carefully cleaned and is free of thick oil or sediment. Use the grade of oil specified in the instructions furnished with the equipment.

The parts of the oiling arrangements of the bearings should be carefully cleaned from time to time, great care being taken that they do not become clogged, especially the vents, as clogged vents will prevent the oil gauges from correctly indicating the level of the oil in the oil well. Oiling rings should turn freely on the shaft when in operation, distributing oil over the shaft. Great care should be taken to keep them smooth and true, as an uneven, flattened, or eccentric oil ring will not function properly.

Care of Controlling Appliances.

The major considerations in the care of controlling appliances are that they be kept scrupulously clean and free of moisture, the contact surfaces free of burns and blisters, all connections clean and tight, and that they be operated within their rated capacities.

The care of fuses, switches, circuit breakers, and rheostats has been discussed under "Switchboard Appliances" and will not be repeated. The interior of all controllers should be inspected after they are used and all defects remedied.

Panel-Type Controllers.—The panels should receive the same care as outlined for switchboard panels. The starting arm should work freely and make positive and efficient connection with the contacts. These contacts should be kept smooth and free of burns or blisters, and if repeated trouble is experienced in this respect, it indicates that they are loose, are being overloaded, or that the successive steps of the resistance are not of the proper values to effect even acceleration of the motor. When overhauling, care must be exercised not to damage the insulation of the rheostat connections to the contacts, as it usually becomes very brittle after long service. The coils of the no-voltage and overload release mechanisms should be kept free of moisture, oil, and other foreign matter, and the moving parts of these mechanisms should work freely.

It will usually be found that the first active contact is subjected to more burning than the others, and will require more attention.

The speed of a motor should never be regulated by means of the starting resistance, as the starting resistance will not carry the required currents for any great length of time without being burned out. If equipped with field rheostats for speed control, the speed changes should be effected slowly in order to allow the motor sufficient time to adjust itself to the condition of stronger or weaker field.

Drum Controllers.—The main points to be considered in the care of drum controllers are: that the drums work freely; that the contact surfaces of the rings or segments are perfectly concentric with the shaft of the drums; that the arc deflectors are intact; that the contact fingers are properly aligned and in good condition; that the blowout coil is functioning; that the leads inside of casing are so secured that they cannot rub on contact surfaces, and that the controllers are kept clean. The bearings should be lubricated occasionally with oil, and contact segments and rings lightly lubricated with vaseline to prevent cutting, but care must be taken not to use too much as it is apt to cause burning and blackening of the contacts. Care should be taken that the gaskets of controllers having watertight covers have not become broken or loosened, but that they are always in place, and the cover tightly clamped. Attention should be given also to the bushings surrounding the lead wires, where they come through the frame of the controller, making sure that they have not slipped out of position. The stuffing boxes at the top, when installed, should be kept well packed, so that water will not enter around the shaft. Drum controllers are generally provided with a projecting brass ring, called the water cap, which, while not absolutely watertight, answers all ordinary requirement of water protection. The projections on the shafts and other bright steel parts should be occasionally slushed to prevent rusting. Electrical connections should be kept tight.

Contactor Type Controllers.—Contactor type controlling appliances should receive the same general care as described above, the most important points being to make certain that the accelerating and interlocking features are operative and functioning in proper sequence, as designed. The contact points of the accelerating and interlocking devices should be smooth, free of burns or blisters, and make perfect contact, to prevent the possibility of one or more of the contactors failing to operate, which might result in burning out the starting resistance.

Rheostats.—Rheostats should be kept clean, dry, connections clean and tight, be operated within their rated capacities, and be frequently inspected and tested.

If a rheostat gets wet it should be dried by baking the rheostat in an oven, or by passing a *limited* electric current through the resistance element. The latter method should be conducted very cautiously and under the direct supervision of an experienced electrician. Moisture may cause oxidation or electrolysis of the element, in which case economical repairs may be effected if the damage is localized, but if these defects are distributed throughout the element the only remedy is to renew the element, being very careful to use elements of the same resistance as those which were damaged.

The air spaces of the rheostats should be blown out occasionally to free them of foreign matter, using a hand bellows or a blast of dry compressed air for the purpose.

Care and Management of Search-lights.

Search-lights are exposed to the weather, and great care is necessary to keep them watertight in order to protect the connections and working parts.

The search-light covers are usually kept off during the day, and moisture from rain or spray is very likely to find its way through the vents or through defective joints into the barrels.

All search-lights should be inspected daily, in the forenoon, and made ready for use:

(1) Examine the carbons, and renew them if necessary.

(2) Test the feeding mechanism. It should work freely, and smoothly, and all parts should be tight. Wipe dry any parts that show signs of moisture.

(3) Inspect the barrels for leaks.

(4) Move each search-light vertically and in azimuth. They should move freely, without binding.

(5) Test distant control apparatus if fitted.

(6) Examine the switch in the base for burns or blisters, and for moisture.

(7) Lubricate working parts of search-lights and mounts where necessary, and remedy all faults.

(8) Dust off the mirrors and glass strips with a soft dry rag, and polish with chamois.

(9) After the inspection is completed, operate the light, striking an arc. Keep it in operation long enough to insure that all moisture is expelled from the carbons.

The attendant should assure himself that the light is in all respects ready for instant use before leaving it.

When putting on or removing search-light covers, care must be exercised to avoid damaging the glass strips in the front doors, or the telescope sight brackets, if fitted.

Occasionally the search-lights should be lifted clear of the roller path, and the rollers and paths cleaned.

Occasionally the entire lamp mechanism should be taken to the work shop and thoroughly cleaned and oiled, and all repairs made that are required. This work should not be attempted on the search-light platforms.

Strict attention is necessary when operating to maintain a good arc. Carbons will be encountered that have hard spots, burn off center, create mushrooms, etc.

The search-light rheostats require the same general care as outlined under the heading "**Rheostats.**"

The most satisfactory **focus** is found when the beam of the search-light is projected with minimum divergence; if the beam is diverging, the lamp should be moved away from the mirror, and if converging, it should be moved nearer to the mirror.

When illuminating targets, the beams should never *strike* ahead of the target, as it will cause fogging, and the gun pointers will not see the target clearly.

The **mirrors** should never be exposed to the direct rays of the sun, as it will result in injuring the silvering. The silvering should be protected from moisture with a uniform coating of the following paint:

Turpentine asphaltum	1 qt.
Damar varnish	4 oz.
White lead	2 oz.
Turpentine	3 oz.

Dissolve the white lead in the turpentine, add the other ingredients, and mix thoroughly.

This makes an excellent black waterproof paint for mirror backs, and dries in about one hour. The mirrors should never be subjected to severe temperature strains, as opening slide doors, or removing the front door, then training the search-light into the wind while it is in operation, or while it retains appreciable heat from previous operation. Never elevate the search-lights while in operation so high that pieces of incandescent carbon may fall on the mirror, as the mirror may be ruined, or at least have portions of the silvering destroyed. The practice of using search-lights in a low position for the purpose of illuminating colors at the trucks is injurious.

Important Instructions for Operation.

There are certain general operations which should invariably be done in the same manner when managing electrical apparatus and which have been given in the preceding under the heads of different appliances described. These are collected and given below in two lists, "Always" and "Never," in order that they may more easily be remembered and referred to.

"Always."

Always close the field switch before the armature switch.

Always open the armature switch before the field switch.

Always open switches carrying field currents slowly, allowing the field discharge to dissipate at the contacts.

Always close switches provided with field-discharge resistances as far in as they will go.

Always open the series-field shunting switch on the main switchboard after operating a generator with a Ward-Leonard system.

Always throw a controller to the "off" position immediately when the circuit breaker opens.

Always see that the arm of the automatic release rheostat on controlling panels comes to the "off" position when the main switch is opened.

"Never."

Never close a series-field shunting switch on the main switchboard unless the generator is to operate with a Ward-Leonard system.

Never run a controller between notches.

Never open the field circuit of a motor while the main switch is closed.

Never run a gun-elevating motor at full speed when near the end of its train, or when depressing an empty gun or elevating a loaded gun.

Never start an ammunition-hoist motor until the hoist cover has been removed and the delivery table turned out into position.

Never start an ammunition-hoist motor in the lowering direction until the safety pawls have been raised.

Never cut out the running- and signal-light circuit between sundown and sunrise if underway.

Never cut out the fire- and engine-room circuits, if underway, without the sanction of the engineer officer on watch.

Never cut out the gyro-compass circuit when the gyro is in operation.

Never cut out any circuits, except in emergencies, without obtaining authority and notifying the personnel affected, so that they may make necessary dispositions.

Tests and Inspections.

Tests and inspections have been considered in the discussion of the care and operation of the various appliances. It cannot be too strongly emphasized that thorough knowledge of performance and of the condition of the electrical plant, as obtained by properly conducted inspections and tests, is essential if it is to be maintained in a high state of efficiency. The following is a routine of tests and inspections required on board one of the modern battleships:

EACH WATCH:
  Clean switchboards.
  Inspect and oil running motors.
DAILY:
  Ground test.
  Turn over generators not in use (except when laid up for overhauling).
  Operate search-lights.
  Operate auxiliary lighting relays.

Test telephones—salvo systems.
Test navigational apparatus.
Test general alarm gongs and howlers.
Inspect covers of all distribution and fuse boxes, etc.
Test auxiliary lighting.
Test storage batteries—gun firing and range finder.

WEEKLY:
Inspect and operate all motors that have not been operated for one week.
Inspect all fuses.
Check up all articles of equipage title "B."
Inspect storage batteries for height of liquid, creeping salts, etc.
Inspect fingers of all controllers.

MONTHLY:
Submit summary of kilowatt-hours used for various purposes.

QUARTERLY:
Take insulation resistance of all circuits.

BEFORE FIRING:
Take insulation and metallic resistance of director firing circuit.
Inspect action cut-out boxes of visuals.

Care of Spare Parts.

An accurate list of the spare parts furnished with the electrical equipment should be kept, the location and quantity of each type of spare part being clearly indicated therein.

It is very important that whenever spare parts are used, steps be taken to replace them without delay, in order to have the allowed quantity available when required to meet emergencies.

Spare parts should be stowed where they will be free of moisture, and every spare-part box should be accessible.

Spare parts which are subject to oxidation, such as steel or iron parts for engines, should be coated with a mixture of white lead and tallow to prevent rust. Those of composition metal should be lightly vaselined to prevent formation of verdigris and to preserve the original finish. Certain small spare parts, such as sockets, attachment plugs, etc., may be left in their original packages if their oiled paper wrappings are intact.

Armatures are usually packed in zinc cases, and securely boxed, in which case the major consideration will be to have the boxes marked plainly and indelibly as to their contents, to prevent opening the wrong box when a spare armature is required. If not so packed, they should be covered with fitted canvas covers, the commutator being additionally protected by a strong canvas wrapping, and the shaft coated with white lead and tallow. They should be mounted so that their weight will be carried by brackets, and should be turned occasionally to prevent them from becoming unbalanced.

If an armature is replaced by a spare, the damaged armature should not be stowed in the spare armature's casing, but repaired and made ready for use before being stowed away. If repairs are beyond the capacity of the ship's force, steps should be taken to replace the armature.

Care of Store Rooms.

Store rooms should be kept scrupulously clean, neat, and free of moisture. They should be equipped with suitable lockers, shelves, and drawers, and the contents of each plainly marked on cards tacked or otherwise secured to them. *The cards must be kept corrected to date to be of any value.*

Lamps should be kept in specially prepared shelves, the different candle-powers being grouped together. Wires should be kept on reels, properly marked with the size and number of feet on each reel. All small articles such as screws should be assorted in sizes and kept in appropriate boxes, and small fittings should be laid out flat and neatly arranged.

Portable fixtures, such as signal lanterns, should have their conductors coiled up neatly around them and be hung on hooks from overhead, each marked as to length of its conductor.

Special care should be taken with breakables, such as globes, shades, spare lenses, spare screens. It is a good plan to keep them packed in excelsior and in a separate locked compartment.

Spare conduit can be strung overhead along the beams, elbows or bends being kept in barrels or laid out on the shelves.

All instruments should be kept in their individual cases and kept locked if fitted with locks.

As far as possible the floor space should be kept free to allow as much space as possible for moving around, and for handling stores.

No persons except those authorized to do so should be allowed to take articles from the store rooms, for in this way only can a proper expenditure be kept. The store rooms should be habitually locked in the absence of the store-room keepers.

Care of Work Shop.

The work shop should be cleaned up frequently during the day, and when the day's work is completed hand tools should be cleaned and stowed, machine tools cleaned, the benches brushed off, the deck swept clean, and the buckets emptied and cleaned. All parts of incompleted jobs should be grouped together in such a manner as to eliminate possibility of misplacing or losing any of the parts.

When a job is in progress, it is a good plan to place all of the small parts in a small box as soon as they are disassembled.

A system should be established which will keep track of all portable tools and instruments, each item issued being charged to the actual custodian until return.

When repairs are being made to portions of the equipment, careful inspection should be made to insure that each job of repair is thoroughly done, endeavoring to instil into the force the idea that there should be no distinction, in the broad sense, between ship repairs and factory repairs.

Each job should be thoroughly mapped out, the successive steps of the work taken up in proper sequence, and when completed should be rigidly inspected and tested before being sent out of the shop.

Allow no unauthorized work to be done in the work shop, and when laying out the day's work, arrange it so that the most urgent jobs will be taken up first.

The stowage of the tools in the work shop should be such that any tool can be found without delay. The tools should be kept free of rust, adjustable tools working freely.

APPENDIX

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SPECIFICATIONS FOR TURBO-GENERATING SETS.

FOR USE ON BOARD SHIP.

(December, 1913.)

1. **General.**—Each set shall consist of an electric generator driven by a steam turbine, both mounted upon a common bedplate, or having a common frame provided with ample supporting feet. The turbines shall be complete with throttle valve, and shall not require auxiliary ventilation or water supply for other than oil or bearing cooling.

2. **Dimensions and Weights.**—The set as a whole shall be as compact and light as is consistent with due regard to strength, durability, and efficiency. The maximum allowable normal speed, weight, over-all dimensions, and clearance for disassembling shall be as follows:

Kw.	R. P. M.	Length over all.	Base width.	Height over all.	Width over pipe connections.	Clearance for assembly.			Weight. in pounds.
						Top.	Turb. end.	Comt. end.	
		Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	
5	4,000	58	25½	31	25	12	3	....	1,200
10	4,000	75	37	41	31	16	5	....	2,000
25	3,600	90	38½	41	42	16	13	5	4,300
50	3,300	110	54	60	54	20	16	6	9,500
100	2,400	140	62	82	72	24	12	8	17,500
200	1,700	174	78	92	100	36	6	3	29,000
300	1,500	175	78	92	100	36	6	3	32,000

3. **Accessibility.**—The design shall provide for accessibility to all parts requiring inspection during operation or adjustment when under repair. Sets of 100 kw. capacity and larger shall be provided with couplings between the armatures and turbine wheels to permit the removal of the armatures without disassembling the turbines.

4. **Operation.**—The set must be capable of running without undue noise, excessive wear or heating; must be balanced and run true at all loads up to 33⅓ per cent about rating; and must be capable of running for long periods under full load.

5. **Bearings.**—Both upper and lower halves of main bearings are to be removable without removal or displacement of shaft, on sizes 50 kw. and over. Bearings will be provided with babbitted or bronze linings. Standard composition for bearing-bronze is: Copper 83 per cent, tin 13½ per cent, zinc 3½ per cent. Suitable thrust bearings will be provided to prevent such movement of the shaft in direction of its length as might be caused by pitching of the ship with set erected with its shaft extending fore and aft. Circulating water coils will not

be embedded in material of bearings. All bearings will be readily replaceable. Means will be taken to prevent oil from running along the shaft.

6. **Bedplate.**—The bedplate, where used, shall be a substantial casting provided with accurately spaced, drilled holes for securing to foundation.

7. **Bolts and Nuts.**—The seats for all boltheads and nuts shall be faced. All external nuts subject to frequent use shall be casehardened, and all nuts shall be United States standard size. Where liable to work loose from vibration, nuts shall be securely locked. All both ends shall be neatly finished.

8. **Doweling.**—Adjoining portions of the machinery, where efficiency and good operation are affected by alignment, shall be doweled or rabbeted together, dowels to be fitted to accurately reamed holes. Through dowels in all cases shall be provided with threads and a nut for withdrawal. Adjoining portions of the machinery shall be given corresponding marks when desirable for insuring correct assembly.

9. **Tools.**—Necessary special wrenches, lifting eyes, jacking-off bolts for removing wheels, and all special tools, feelers, etc., required for assembling and disassembling the generating set shall be furnished, mounted on a board suitable for mounting on bulkhead. Where more than one generating set is installed in a dynamo room, one set of tools will be furnished for each dynamo room.

10. **Templates.**—If required in advance of delivery of set, templates of the combination bedplate and of the shunt field rheostat and handles shall be furnished by the contractor free of additional expense. These may be of paper, full size, with dimensions entered complete in order to obviate errors due to shrinkage or expansion.

11. **Interchangeability.**—Interchangeability among the different sets and their spare parts, of the same size and make as furnished in any one contract, is required. This is to be demonstrated as part of the final test for acceptance.

12. **Boxing of Spares.**—Spare parts supplied shall be boxed and protected in accordance with the latest standard specifications.

13. **Defects.**—The general appearance of the set resulting from design and workmanship must be of the highest character. Any defect not caused by misuse or neglect, which may develop within the first six months of service, shall be made good by and at the expense of the contractor.

14. **Facilities for Inspection.**—The works in which the construction of the machines is being carried on shall be open at all times during working hours to the inspecting officer and his assistants, who shall have the right to follow the material through all the processes of manufacture. Every facility shall be given such inspectors for the proper execution of their work.

15. **Drawings.**—(a) Bids shall be accompanied by a drawing showing the longitudinal section of generator and turbine assembled complete; an outline drawing, plan, and elevation showing over-all dimensions and weight of the proposed set, clearances necessary for assembling, size and location of all proposed pipe outlets, drains, and foundation bolt holes, and, if required, detailed drawings of forced lubrication system, bearing construction, or other parts which have not previously been approved by the Bureau of Steam Engineering, and for which plans are not on file in the bureau.

(b) After preliminary acceptance of the generating set, a complete set of first-class detail and assembly drawings on tracing cloth shall be supplied. The drawings must be accurate in every respect, and must represent the different parts of the set as they will appear when the set is finally accepted by the government. These tracings are required for the bureau's files; and the necessary prints shall be made by the bureau for the record of electrical appliances and other plans which may be required.

(c) If tracings of any of the plans referred to under paragraph 15 (b) are on file at the Bureau of Steam Engineering and are correct in all respects for the material in question, duplication of the same is not required.

There shall be forwarded to the Bureau of Steam Engineering, however, in the case of each order, a plan showing the following:

Numbers of plans showing—
  Assembly views and sections referred to in paragraph 15 (a);
  Details of all parts;
  Connections;
  Brush size and number.
A list of spare parts and accessories furnished.
Generator, turbine, and armature numbers.
Name-plate data.
Normal steam pressure for which designed.
Schedule, requisition or contractor's order number.
Vessel or station for which intended.

In addition to the above the plan shall clearly state whether the plans referred to are on file at the Bureau of Steam Engineering or are forwarded to the Bureau of Steam Engineering with the order in question.

(d) The scale of all drawings shall be clearly indicated.

(e) The size of sheets shall conform to dimensions shown on Bureau of Steam Engineering plan No. 1266.

16. **Factory Tests.**—The contractor shall make, at his own expense and previous to test by government inspector, sufficient tests to insure that the sets conform in all respects to the specifications. The inspecting officer shall be previously notified as to the time of these tests in order that he may be present to witness them if he so desires.

17. **Tests by the Government.**—To prevent delays and additional cost to the government of repeated tests, no more than two tests will be made, the second test to be made within such time after the first test as may be stipulated by the bureau. Failure to make the necessary repairs or remedy defects within that time will be cause for final rejection of the set. If left upon government property while undergoing repairs, the risk of loss by fire will be carried by the contractors. Contractors will afford adequate facilities for the inspection of apparatus under manufacture. All tests will be at the works of the manufacturer, unless otherwise provided by the bureau. The contractor will notify the bureau at least 10 days in advance of the date when sets will be ready for official test.

All necessary facilities and apparatus for conducting prescribed tests will be furnished by the manufacturers.

No shipment will be made without authority of the bureau or its inspectors.

Inspectors will authorize shipment when tests conform to specifications. The contractor is responsible for the delivery of sets at designated place in the presence of a government inspector in the same condition as when shipment was authorized.

18. **Intent of Specifications.**—It is the intent of these specifications to produce a generating set which shall be first class in every particular relating to design, construction, and operation. Any omission from these specifications, or omission

of any part of the machinery necessary to produce above results, or failure to describe design and construction of same, shall not operate to release the contractor from supplying such part of the machinery or from performing such work as part of the contract without additional expense to the government.

19. **Patents.**—The contractor shall forever protect and defend the United States in the full and free use and enjoyment of any and all rights to any invention or device which may be used in the construction or whose use may be required for the successful operation of the generating sets against any and all persons or corporations.

TURBINES.

20. **Type and Capacity.**—The turbine shall be of the horizontal type, designed to ordinarily run condensing, but capable of operating at 90 per cent full load non-condensing with 5 pounds back pressure. The turbine shall be of sufficient power, when running condensing, to drive the generator for an indefinite period at rated speed when the generator is carrying 1⅓ load.

21. **Valve Gear.**—On all turbines operating condensing, the valve gear shall work automatically over the total range of conditions without the adjustment of hand valves or similar devices. The words "total range of conditions" shall be interpreted to mean operation from zero to one-third overload condensing, when operating with normal steam pressure and minimum vacuum of 25 inches. For non-condensing operation, sets may be equipped with one hand valve, which will be marked "Open for non-condensing operation only."

22. **Water Rates.**—With normal steam pressure of 200 pounds dry saturated steam, the steam consumption for half and full loads shall not exceed the following:

WATER CONSUMPTION.

Rated Kw.	Maximum R. P. M.	Kw. load.	Pounds water per Kw. hour at 25 inches vacuum.
5	4,000	2.5	100
		5	70
10	4,000	5	86
		10	61
25	3,600	12.5	66
		25	49
50	3,300	25	48.5
		50	36
100	2,400	50	44
		100	33
200	1,700	100	43
		200	32
300	1,500	150	36.5
		300	29

Corrections in water rate for superheat, moisture in steam, or change from normal steam pressure of 200 pounds will be calculated as follows:

Superheat, 1 per cent for each 10° F.

Moisture, 2 per cent for each 1 per cent moisture indicated by calorimeter.

Steam pressure for pressures above 150 pounds, 1 per cent for each 10 pounds steam pressure.

Superheating may be employed to insure dry steam, a proper correction being applied to the water rate to compensate for the degree used.

23. **Material.**—Buckets, balancing weights, reversing vanes shall be of material which will not injuriously rust or erode under the action of steam. Shafts will be made of class B steel forgings.

24. **Operation under Various Steam and Exhaust Conditions.**—The turbine shall run smoothly and furnish the required power when exhausting to condenser at 25 inches of vacuum for full load at any steam pressure within 20 per cent of normal, and shall furnish power when exhausting into the atmosphere for 90 per cent of full load at steam pressure 20 per cent below normal, and for full load at any steam pressure between normal and 20 per cent above normal. It must be capable of bearing, without injury, the sudden throwing on or off of 1⅓ times the rated load of the generator by making or breaking the generator's external circuit.

25. **Flanges.**—Turbine shall have steam flanges on the right or left side and exhaust flanges at bottom pointing down, or at bottom pointing to right or left, or as may be specified for the different installations. All piping shall be supported at points close to the turbine, so as not to affect the alignment of parts or cause undue strain in turbine casing. Flanges shall conform to bureau drawings B-8-C for steam piping and B-6-D for exhaust piping.

26. **Valves.**—The steam inlet shall be fitted with throttle and emergency valves (combined in one valve, if preferred) equipped with strainer intervening between the valves and the steam line. The emergency valve will be connected to the emergency governor in such a way that it will automatically close between 7 per cent and 10 per cent above normal speed of the turbine.

27. **Governor.**—The governor will be of the centrifugal or inertia type, designed to regulate the speed within specified limits.

28. **Lagging.**—Lagging shall be fitted as extensively as practicable to the turbine. This shall be done *after* preliminary test of the turbine, in order that any defects in castings or joints may be readily found. The arrangement for securing the lagging in place shall admit of its ready removal, repair, and replacement.

29. **Speed Variation.**—The speed variation shall not exceed 4 per cent for sets larger than 25 kw., nor 4½ per cent for sets 25 kw. and under, when load is thrown on or off the generator under the following conditions:

	Per cent load.	Per cent. steam.	Exhaust.
A.	90	80	Atmosphere.
B.	100	100	Do.
C.	100	120	Do.
D.	100	100	Normal vacuum.
E.	100	120	Do.

The speed variation shall not exceed 3 per cent when load is suddenly varied from full load to 20 per cent of full load, or from 20 per cent of full load to full load when operating condensing at normal steam pressure for sets larger than 25 kw. and 3½ per cent for sets 25 kw. and under. No adjustment of the governor or throttle valve during the test shall be necessary to insure proper performance under the above conditions.

30. **Lubrication.**—The turbine shall operate without the use of lubricants in the steam spaces, and suitable provision shall be made to prevent the entrance of oil into these spaces. Forced lubrication shall be fitted on sets of all sizes. All main bearings on which the shaft pressure exceeds 20 pounds per square inch of projected bearing surface shall be cooled by circulating water in coils. Coils to be located in all such cases in oil chamber for cooling oil. If required, additional cooling shall be obtained by circulating water in bearing shell castings.

31. **Mandrels.**—Mandrels, with collars, complete, shall be furnished for renewing the white metal of all bearings so fitted.

32. **Strength.**—The material and design of the turbine shall be such as to safely withstand all strains induced by operation at the maximum steam pressure specified, and by tests noted below.

33. **Name Plates.**—A metal name plate shall be fitted to the turbine in a conspicuous place, marked as follows:

Made for
Bureau of Steam Engineering
by
(Name of maker here)
Reqn. No...... 19......
Type...... Class...... Form......
Kw....... Steam..... Rev........

34. **Accessories.**—The following shall be provided with each set:

(a) One 6-inch brass combination gauge for exhaust casing graduated 30 inches vacuum and 30 pounds pressure.

(b) Two 4½-inch steam seal gauges, 30 pounds scale, for sizes above 25 kw. Two 2½-inch steam seal gauges, 30 pounds scale, for 25 kw. and sizes below.

(c) One 4½-inch oil pressure gauge shall be furnished at the pump, and on sets of 200 kw. and above a gauge shall also be furnished for each bearing.

(d) A pop safety valve, arranged for piping connections, shall be fitted to the turbine casing. To be of size sufficient to protect the casing under all conditions of steam and exhaust pressures, inclusive of those caused by closing the exhaust valve.

(e) The turbine casing shall stand a hydrostatic test of 50 pounds per square inch.

(f) Sets of 50 kw. capacity and above shall be provided with permanently connected direct-reading tachometers of approved type. All sets shall be so designed as to permit the use of a hand tachometer on at least one end of shaft.

(g) Provision shall be made on the discharge side to permit the observation of the flow of oil and cooling water from each bearing. An adjustable relief valve shall be supplied as part of the oiling system. The pump shall be of the rotary type and geared to main shaft.

(h) The oil tank shall be supplied with a sight gauge and a ¾-inch bib cock at lowest point to permit withdrawal of water from the bottom of the tank.

(i) Canvas cover for both generator and turbine, for use while set is in storehouse and after installing during the building of the vessel, shall be supplied as part of the equipment. Cover shall be made of No. 6 white canvas of the best commercial quality and shall contain openings, fastenings, etc., for steam and exhaust pipes. Covers shall be suitably re-enforced where liable to chafe through during period specified.

GENERATORS.

35. **Type.**—Generators shall be of the direct-current, compound-wound type, designed to run at constant speed and to furnish a pressure of 125 volts at the terminals at rated speed, with load varying between no load and one and one-third times rated load.

36. **Frame.**—The magnet frame shall be circular in form with inwardly projecting pole pieces. Sets of 50 kw. and above shall have the magnet frame divided horizontally; the two halves being secured with bolts to allow the upper half with its pole pieces and coils to be lifted for inspection or removal of the armature. The pole pieces shall be bolted to the frame, and dowels shall not be used which would prevent removal of pole pieces without removal of armature. The magnet frames of sets having bedplates shall be provided with feet of ample size to secure firm attachment to the bedplate. Facilities shall be provided for vertical adjustment of the magnet frames of sets having bedplates.

37. **Armature.**—The laminations for the armature shall be accurately punched from the very best quality of thoroughly annealed electric sheet steel. Slots shall be punched in the periphery of the laminations to receive the armature windings. The laminations shall be insulated from each other and shall be assembled on the spider or shaft and securely keyed thereto. Laminations shall be set up under pressure and held securely by end flanges.

38. **Commutator.**—The commutator bars shall be so secured to the shaft that no relative motion can take place between the windings and the bars. The bars shall be of hard drawn copper finished accurately to gauge. The insulation between bars shall be of carefully selected mica of not less than 0.025 inch thick. The bars shall line with the shaft and run true and shall be securely held in place by means of shrink rings.

39. **Brushes.**—The brushes shall be composed of carbon. Each brush shall be separately removable and adjustable without interfering with any of the others. The point of contact on the commutator shall not shift by the wearing away of the brush.

40. **Brush Rigging.**—Brush holders shall be staggered in order to even the wear over the entire surface of the commutator. The generator shall be provided with means for shifting all the holders simultaneously. For interpole generators the brush rings shall be locked so they cannot be easily shifted. All insulating washers and bushings shall be damp proof and unaffected by temperature up to 100° C.

41. **Balance.**—Finished armature shall be balanced both electrically and mechanically, and shall run smoothly and without vibration. Non-corrodible bolts will be used for balancing. Solder for this purpose is prohibited. The shaft shall be provided with suitable means for preventing oil from working along it to the armature. All generating sets shall be tested for strength by a half-hour run at 10 per cent above normal speed. They shall show good balance at that speed.

42. **Copper.**—All copper wire shall have a conductivity of not less than 98 per cent.

43. **Coils.**—The main field coils of any installation shall be identical in construction and dimensions, and shall be readily removable from the pole pieces. This requirement shall also apply to commutating coils. The shunt coils as well as the series coils shall be connected in series.

44. **Connection Boards.**—Connection boards shall be mounted on the generator with necessary terminals for the main, equalizer, and shunt cables. Sets of 50 kw. and above shall be provided with pilot lamps on the machines.

45. **Field Rheostat.**—The field rheostat shall be of fireproof construction, suitable for mounting behind the switchboard unless otherwise specified. It shall be provided with a shaft projecting through to the front, either directly connected or by sprocket chain. Handwheel for front of switchboard shall be supplied and shall be marked to indicate direction of rotation for raising and for lowering the voltage of generator. The total range of adjustment shall be from 5 per cent above to 10 per cent below rated voltage. Variation shall be not more than ½ volt per step between 120 and 130 volts at full load.

46. **Name Plate.**—A metal name plate shall be fitted to the generator in a conspicuous place, to be marked as follows:

Made for
Bureau of Steam Engineering
by
(Name of maker here)
Contract No. . . ., Req'n No. . . ., 19. . . .
Type. . . . Class. . . . Form. . . .
Generator No. . . .
Volts. . . . Shunt current. . . .
Amp. . . . Kw. . . .

The number of the generator shall be stamped on the frame near the name plate. The number of the armature shall be stamped on the end of the shaft or on the coupling flange.

OPERATION OF GENERATOR.

47. **Voltage Regulation.**—The generator shall be flat compounded to within one-half volt either way from normal voltage at no-load and full-load points. The jump in voltage must not exceed 12 per cent when full load is suddenly thrown on or off under all conditions of paragraph 21.

48. **Compounding.**—The compounding test shall be conducted with the turbine working under normal conditions. Field rheostat, shunts, and brushes shall be in fixed positions. Starting at normal voltage at no load, the load shall be increased by steps of 20 per cent to full load and then decreased by similar steps to no load. Accurate readings of voltage shall be made at all points of load. The voltage shall not vary more than 2 volts from a straight line drawn from full-load voltage point to a point one-half way between the no-load voltage points of ascending and descending curves.

49. **Brush Setting.**—The compounding and heat run (full load and overload) of the generating sets shall be made with identical brush positions.

50. **High Potential and Insulation.**—The dielectric strength shall be tested by a continued application of an alternating E. M. F. of 1500 volts for one minute between all field windings, between brush rings of opposite polarity, and between the connected-up generators and the frame. For double-commutator generators with armature windings connected in parallel dielectric strength shall be tested by application of an alternating E. M. F. of 1000 volts for one minute. The test of dielectric strength shall be made with the completely assembled apparatus and not with the individual parts. Insulation resistance of the assembled machine shall not be less than 1 megohm.

51. **Sparking.**—With brushes in a fixed position, there shall be no sparking when load is gradually changed from no load to full load or vice versa; no appreciable sparking when load is varied up to one and one-third load; no detrimental sparking when one and one-third load is removed or applied in one step.

52. **Temperature Rises.**—The temperature rise of the set after running continuously under full rated load for six hours must not exceed the following:

	Degrees C.
Armature	40
Commutator	45
Series field coils	40
Shunt field coils	35
Commutating field	40
Shunt rheostat exposed surface	75
Series shunt	40
Bearings	45

All readings shall be made by thermometers, and generating sets shall not be exposed to strong drafts during tests.

53. **Overload Capacity.**—The generator shall be capable of satisfactory operation for a period of two hours carrying one and one-third times its rated full load in a room temperature of 40° C. without injurious heating or sparking.

54. **Parallel Operation.**—With two or more machines of the same rating and manufacture operating in parallel with any load on the generating plant from zero to one and one-third times the rated load of all machines in operation, each machine shall carry its proportion of the load within 10 per cent of its full-load current. In order that this operation may be secured the equalizer cables shall be such that the resistance of the one having minimum resistance will be not less than 90 per cent of the resistance of the one with maximum resistance. This requirement shall also apply to negative cables. The distribution of current is illustrated as follows: With any number of machines in multiple, each of 1000 amperes rated capacity, the difference between the average load upon *all* machines and the load carried by any one machine shall not exceed 100 amperes or 10 per cent of the normal rating of the machine.

Spare Parts.—There shall be supplied with each order for turbo-generating sets a set of spare parts, of kind and number as follows:

	Number of spare parts required per number of generator sets per order.			
	1	2	3	4
Generator.				
Armature, complete, with commutator and shaft	1	1	1	1
Series field coils, each size and kind	1	1	2	2
Shunt field coils, each size and kind	1	1	2	2
Interpole field coils, each size and kind	1	1	1	1
Bearing linings or bearings, each size and kind	1 set.	1 set.	2 sets.	2 sets.
Brush holder, complete, with 3 additional springs	1	1	2	2
Brush holder insulation	1 set.	1 set.	1 set.	1 set.
Brushes	3 sets.	3 sets.	6 sets.	6 sets.
Turbines.				
Bearing linings or bearings	1 set.	1 set.	2 sets.	2 sets.
Gland packing with springs, or glands complete	1 set.	1 set.	2 sets.	2 sets.
Emergency governor springs	1 set.	1 set.	2 sets.	2 sets.
Main governor springs	1 set.	1 set.	2 sets.	2 sets.
Main governor, complete, including weights, springs, toggles, ball race and seat, etc.	1	1	1	1
Gears, oil pump	1 set.	1 set.	1 set.	1 set.
Oil pump, complete	1	1	1	1
Relief valve for oil system	1	1	1	1
Governor valve stem and seat, complete	1	1	1	1
All other springs	1 set.	1 set.	2 sets.	2 sets.
Thrust-bearing rings, collars, rollers, etc.	1 set.	1 set.	2 sets.	2 sets.
Wrenches, all special types	1 set.	1 set.	1 set.	1 set.
Tools, all required for assembling and disassembling	1 set.	1 set.	1 set.	1 set.

GENERAL SPECIFICATIONS FOR ALL MOTORS.

(Extracts from "General Specifications for Auxiliary Electric Appliances on Shipboard" of November 1, 1916.)

11. Motors will be wound for 230 volts, direct current, unless otherwise specified, and will be open, semi-inclosed, inclosed ventilated, explosion proof or inclosed watertight, with series, shunt, or compound-wound fields, according to the work they are to perform.

12. **Frames.**—For motors above 3 horsepower, unless otherwise specified, magnet frames will be of a high-grade non-fragile cast, wrought, or laminated steel, with machined pole seats or machined pole shoe seats, and will permit of the ready removal of the armature and fields. Poles shall not be secured by dowels in such a manner as to prevent their ready removal. The feet will be machined true and drilled for holding down bolts, which will in no case be less than ½ inch in diameter in motors weighing over 300 pounds.

When delivered to the government frames will be neatly finished and painted a dark color, with a smooth and durable surface.

Unless otherwise approved, the end brackets of frames will be so secured as to permit the bearings to be adjusted for floor, wall, or ceiling support. Armatures will be readily replaceable.

13. In sizes of 5 horsepower and over, motors will be multipolar, preferably with commutating poles. Motors will be as compact and light as possible consistent with strength and efficiency. All motors will be provided at the commutator end with openings of sufficient size and number to give easy access to and a direct view of the commutator and all brushes while in operation. Particular attention will be paid to the arrangement of brushes and handholes of motors for installation in turrets and other confined spaces in order that they may be accessible after installation.

14. All open and semi-enclosed motor frames will be provided with terminal leads which are to be suitably secured at the motor frame. Inclosed ventilated, explosion proof and inclosed watertight motor frames will be suitable for leading in at either side leaded and armored conductors to the terminal connections within by means of watertight terminal tubes, as shown on standard plan (Bu. S. E. No. 2179–L; Bu. C. & R. No. 30099). Unless otherwise specified motors will be delivered undrilled. In the case of open-type motors of 75-horsepower capacity or over, protected terminal boards of approved type will be required. All terminal leads will be provided with suitable connectors.

15. Inclosed watertight motors will be required for all installations where exposed to the weather, or water, and in locations where powder is handled.

Openings will be provided with substantial covers and fastenings of approved design to insure watertightness. Commutator end covers will be removable without the use of tools. The contact surfaces between these covers and motor frame will be smooth and provided with rubber gaskets. Rubber gaskets and sheet packing for all watertight work will be in accordance with the latest Navy standard specifications for the same as issued by the Navy Department, and will be securely attached to the covers by being embedded in a groove or held down by metallic binding strips. All inclosed motor frames will be provided with composition drain plugs at an accessible point.

The degree of watertightness required for inclosed watertight motors is such that a stream of water from a hose under head of about 35 feet and from a distance of about 10 feet can be played on the motor for several minutes without leakage. This test may be required by the bureau, upon one or more motors of a type, to demonstrate this feature.

16. Inclosed ventilated motors, which will be used only when specifically approved, will be similar in construction to inclosed watertight motors except that self-contained means for forcing a stream of outside air over the windings may be provided. The air intake and exhaust will be so located and constructed as to exclude water falling directly on the motor, and will be fitted with bronze wire screens with openings not greater than ¼ square inch area.

16a. Explosion-proof motors, which may be used on submarines and with woodworking tools, will be capable of withstanding any explosion of gas that may occur within them and will not transmit the flame to any inflammable gas outside. Gaskets may be of felt or other suitable material and need not be watertight.

17. Semi-inclosed motors will be provided with substantial ventilated covers of approved type, which are removable at the commutator end, without the use of tools.

Manufacturers' standard designs corresponding to best commercial practice will be acceptable.

18. **Name Plate.**—A name plate bearing the following data will be attached to the motor frame: Name of manufacturer; shop number; manufacturer's type and class; year of manufacture; the winding, voltage, amperes, kilowatt, and horsepower output, time rating, and revolutions per minute; the bureau by which ordered; also space to be provided for stamping the purpose for which intended; the name of the vessel on which the motor is used; and the initials and official stamp of the inspector.

The kilowatt marking will be carried to and include the second decimal place.

The armature number will be stamped on the commutator end of the shaft.

19. **Non-Corrodible Materials.**—In order to prevent deterioration and corrosion all interior bolts, nuts, pins, screws, terminals, brush-holder studs, springs, etc., also handhole cover bolts and such other fittings as the bureau may direct, will be of non-corrodible material or of steel thoroughly sherardized or heavily copper plated.

20. **Connections.**—All connections liable to become loose by vibration will be provided with approved efficient locking devices. All connecting wires and other current-carrying parts will be so proportioned that no undue heating will occur when they are worked under the most severe service conditions, and such connections will be secured in a reliable manner to prevent their coming in contact with the moving parts.

All field connections, where practicable and especially those which it is necessary to break in separating a split-frame motor, will be made at the commutator end.

All connections will be properly marked to facilitate connecting up.

All terminal leads and shunt-field connections will be made with flexible stranded insulated wire, and no wire smaller than 4000 C. M. will be used.

21. **Fields—Coils.**—All field coils will be interchangeable and series connected. Commutating poles will be fitted with series-wound coils subject to the same requirements as series fields. The windings of all field coils will be well protected from mechanical injury and will be thoroughly impregnated, after winding, by the

vacuum process or other approved method or during the process of winding by means of a waterproof insulating compound not soluble at operating temperatures in oil or grease. No insulating substances will be used that can be injured by a continuous temperature of 90° C.

Edgewise-wound series coils will be insulated from the field poles and between convolutions by horn fiber or other approved material. Enamel insulated wire of approved manufacture may be used when wound on an insulating spool with a dead protecting layer or when suitably taped.

22. **Armatures.**—The disks will be properly insulated from each other and the coils will be securely retained in slots of the armature body. Armature coils will be form wound and removable in sizes above 2 horsepower. The armature must be electrically and mechanically balanced. Armature windings will be thoroughly treated with waterproof insulating compound not soluble at operating temperatures in oil or grease.

Armatures of motors of 5 horsepower and over shall not be balanced by the use of solder on band wires.

The armature shaft will be of steel, strong enough to resist appreciable bending under any condition of overload, and will have sufficient bearing surface, and be efficiently lubricated by self-oiling bearings.

23. **Bearings.**—Bearings will be provided with babbitted or bronze linings, lubricated by balanced soft-metal oil rings which run true, or may be roller or ball bearings, as hereinafter provided. The following is an approved standard composition for bearing bronze:

	Per cent
Copper	83
Tin	13½
Zinc	3½

Each oil chamber will be liberal in size and provided with an opening or composition standpipe of the proper height to prevent overfilling, not less than ⅜ inch in diameter for motors above 3 horsepower and not less than ¼ inch for motors of 3 horsepower and under. This opening will be conveniently adapted for use in filling the bearing with oil and will be fitted with an oil-tight plug to prevent the escape of oil which might result from the motion of the vessel. In inaccessible spaces this standpipe will be carried out to a convenient location by a pipe attached to the motor frame. It must be possible to place the hand on the bearings during operation.

The opening at the top of the bearing for inserting or examining the oil rings while running will be protected by a cover secured by brass screws or in other permanent manner. This cover, which will be watertight for inclosed motors, will be removed only in case access to the oil ring is desired, and will not be used for filling.

The oil will be prevented from following along the shaft or escaping from bearings by deflecting flanges on the shaft, and also by packing around the shaft at both ends of the back bearing, the inner end of the front bearing and plate with gasket at outer end or by other approved means. This will serve also to exclude water from the bearings of watertight motors.

Provision will be made for draining oil from the chamber by means of a threaded bronze taper plug.

Self-lubricating bushings will be used only upon the bureau's approval for each type of motor. Ball or roller bearings arranged for grease lubrication may be used where not subjected to unusual shock.

24. **Commutators.**—Commutator segments will be of best quality hard-drawn copper. The segments will be of ample depth and insulated from each other by mica or pressed mica plate and the shell by pressed mica plate or other approved material; the mica between the bars will be of such quality as to secure even wear with the copper also good commutation and may be undercut so as to form a V-shaped groove between segments not to exceed $\frac{3}{64}$ inch below the surface of the commutator.

25. **Brushes.**—Brushes will be of carbon or a combination of graphite, rectangular in section, and the current density will be such as to insure good commutation. Special attention will be given to the selection of brushes, that their material may be homogeneous and the quality such as will give satisfactory commutation without chattering and without cutting or smearing the commutator.

26. **Brush Holders.**—Brush holders will be readily accessible for adjustment and renewal of brushes and springs and will be entirely of non-corrodible metal. If the brush slides in the holder, it must be provided with a flexible copper connection between the brush and holder. The springs will be phosphor bronze or steel, protected by heavy copper plating or other approved non-corrodible coating, and will not be depended on to carry current. Brush holders on all motors will be adjustable for spring tension, and on motors of 5 horsepower and above will be adjustable for tension without tools, and so constructed as to permit of proper staggering of brushes. Brush holders will be simultaneously adjustable for position. The proper position of the rocker arm will be plainly marked.

MOTOR TESTS.

27. The contractor will notify the bureau or its authorized representative in every case at least 10 days in advance of the date when the apparatus will be ready for official test, and upon receipt of such notice an inspector will be detailed to witness the tests, or manufacturer's certified test reports in duplicate will be accepted at the option of the bureau. Apparatus will in no case be shipped from the works of the manufacturer without written authority from the bureau or its authorized inspector. (See par. 32.)

The inspector will authorize shipment upon the completion of tests showing that the apparatus is in compliance with the approved specifications and plans.

Items of non-compliance which cannot be corrected to the satisfaction of the inspector will be referred by him to the bureau for its action. When shipment is authorized, test reports, accompanied by the manufacturer's shipping list, certified by the inspector and "Report of material shipped," will be forwarded by the inspector to the bureau and to the commandant at the navy yard for which the material is intended (or the officer in charge at shipyards in the case of vessels under construction), together with a statement as to whether or not there was any delay in the inspection of the apparatus which was attributable to the government.

The method of conducting tests will be as specified.

Test reports will be submitted in accordance with standard blank form, copies of which may be obtained upon application.

28. The contractor will be responsible for any damage resulting during shipment of material to place of delivery.

29. The tests will cover the following points:

(*a*) Adjustment and fit of parts (each motor).

(*b*) Mechanical strength of parts against breaking or displacement (each motor).

(*c*) Balance of armature (each motor).
(*d*) Noise (each motor).
(*e*) Sparking at commutator (each motor).
(*f*) Variation of speed under different loads and temperatures (each motor).
(*g*) Dielectric strength (each motor).
(*h*) Heating (each motor).
(*i*) Efficiency and weight (one motor each size and type).
(*k*) Lubrication (each motor).

(*a*) **Adjustment and Fit of Parts.**—The materials and workmanship of all parts of the machine are to be of the best quality and satisfactory in every respect.

Motors will be tested in the direction of rotation in which they will operate after installation.

(*b*) **Mechanical Strength.**—The base, bearings, shaft, armature, field magnets, and other main parts should not spring with any reasonable force that may be applied to them. The strength to resist strains due to centrifugal force will be tested by running the armatures of shunt motors without load for 30 minutes at double their rated speed, of compound motors at double their no-load speed, and of series motors at four times their full-load speed for the same period, provided such speed does not result in a peripheral speed of the armature of over 6000 feet per minute.

No high-speed test for any purpose will be made in excess of 6000 feet per minute, peripheral speed, unless a peripheral speed of 5000 feet per minute will be exceeded in actual service, in which case the high-speed test will be made at 20 per cent above the highest attainable service speed, except that this test in the case of motors for use with centrifugal pumps will be made at no-load speed of the motor. The armature coils and commutator bars should show no signs of having been displaced by the above speed test.

(*c*) **Balance.**—The perfection of balance of the armature will be tested by running shunt motors at their normal speeds, compound motors from normal speed to 25 per cent above normal, and series from normal to double their rated speeds, at which speeds the motors must not show objectionable vibration.

(*d*) **Noise.**—The motor will run at all speeds and loads within its range without objectionable noise.

(*e*) **Sparking.**—Motors will run from no load to 25 per cent overload without objectionable sparking and without shifting the brushes and under all conditions of full and weak field when field regulation is used. All overloads mentioned above and in the following specifications will be measured in terms of full-load current input, and the commutation during such overload tests must not be such as to cause rapid deterioration of the commutator and brushes.

(*f*) **Variation of Speed.**—For shunt motors the variation in speed from full-load hot to one-fourth load hot will not exceed the following, based on the full-load speed hot:

	Per cent
Constant speed motors....................................	10
Adjustable speed motors (based on heat run speed)....	15
Motors with speed ratio of over 1 to 4.................	18

The variation in speed from full-load cold to full-load hot for all motors during the specified heat run will not exceed 10 per cent, based on the full-load speed hot.

The full-load speed hot for all motors, except centrifugal pump motors (see par. 179), must be within 5 per cent of the rated speed.

Commutating pole motors shall not run at a speed more than 2 per cent in excess of the no-load speed during overload tests specified under the detail specifications as of 5 minutes' duration or over.

(*g*) **Dielectric Strength.**—The test of dielectric strength will be made at about the temperature obtained at end of heat test. A test pressure of alternating electromotive force supplied by a generator or transformer of at least 5 kw. capacity shall be applied, for 60 seconds, between each electric circuit and all other electric circuits and metal parts grounded. The test will be applied between shunt and series windings. The test voltage shall be 1500 alternating current for motors of 1-horsepower capacity and over, and 1000 volts alternating current for motors of less than 1-horsepower capacity. Apparatus which has broken down in service and has been repaired will be tested at 750 volts. No resistance will be connected in series with the testing circuit to limit the current at breakdown.

(*h*) **Heating.**—All temperature measurements will ordinarily be taken by thermometer in accordance with the appended directions. (See pars. 357-364.)

The following are the maximum observable temperatures and temperature rises, ° C. allowed for all motors:

Part.	Ultimate temperatures.	Temperature rises.	
		Continous duty.	Intermittent duty.
Windings:			
Impregnated fibrous material and enamel insulation	90	55	60
Commutator	100	60	65
Bearings	80	40	45

Windings for which heat runs of more than 2 hours' duration are specified will be considered as subject to continuous duty. All others will be considered as subject to intermittent duty unless otherwise specified.

Observations of temperatures will be taken at the end of the full-load heat run which, in the case of adjustable speed motors, will be made at the low speed. The length of heat runs will be as specified for each auxiliary based upon the nature of the duty in service.

In determining temperature rise no correction for air temperature, barometric pressure, or humidity will be made.

The use of a resistance in motor-field circuits to limit temperature rise will not be approved.

The specified overload tests are intended to determine mechanical strength and electrical overload capacity without regard to temperature rise. These tests, which should be applied while the motor is hot, will be started at such a temperature as not to cause the ultimate temperatures above specified to be exceeded.

Where applicable, consideration will be given to the use of motor or brake windings, protected by non-combustible waterproof insulation, in which case an ultimate temperature and temperature rise not exceeding 110° and 75° C., respectively, will be allowed. In such cases the allowable temperature rises will not exceed 50° for bearings and 75° for commutators. This form of insulation will be permitted only upon approval by the bureau, and must have been in successful commercial use for more than one year prior to its installation on shipboard.

When the shunt fields of intermittent-duty motors, or the coils of clutches or brakes will be continuously energized in service, they will be subjected to a heat test of such duration (not to exceed 8 hours) as will not be exceeded in service, and at the same excitation as in service.

(*i*) **Efficiency and Weights.**—Motors on shop test must meet the approved efficiencies guaranteed by the contractors. Preference will be given to lightest weight and best efficiency consistent with good design and the specific requirements. Efficiencies will be determined with brake and oil washers in position, if used.

(*k*) **Lubrication.**—The oil rings must run freely and properly lubricate the bearings; the necessary overflow gauges and drain plugs will be furnished.

BRAKES, CLUTCHES, ETC.

30. Unless otherwise specified, electric brakes, clutches, etc., will be subjected to the same heat and insulation tests as the apparatus to which they are attached, and the coils will be subject to the same heating limits as field coils. Series brake coils will be given the same tests as the series field coils of the apparatus to which they are attached. Shunt-wound coils will be impregnated with a suitable insulating compound by the vacuum process in a manner similar to that specified for field coils, unless otherwise protected against damage from moisture and the inductive discharge to the coil, in an equally effective manner. Shunt-wound brakes and clutches must operate satisfactorily at 70 per cent of rated voltage, tested at the temperature obtained at the end of the heat test.

The heat test of disk brakes or clutches may be made at the time of the field test, and the armature will be at rest or turning as specified.

Brakes will be provided with connection boxes arranged for the entrance of leaded and armored wire as required for motors (see par. 14) and will be watertight when used with watertight motors.

Name plates will be provided for brakes unless the brake data is included on the motor name plate.

SPARE PARTS.

31. Electrical and mechanical spare parts will be supplied for each appliance by the contractor and at his expense. The spare parts will be in general accordance with the list, paragraphs 338-342, and must be interchangeable, so that each will fit any appliance of the same size and type for which it is made, and the fact that they do so fit must be demonstrated by actual test.

All spare parts will be boxed in accordance with instructions for boxing spare parts, paragraphs 343-356.

Spare armatures will include shaft and commutator and will be subjected to the same tests as originals.

When it is impracticable to obtain the proper machines in which to conduct the above tests, spare parts will be given the regular high potential test; armatures will be given a magnetic (either static or rotary) or bar to bar drop of potential test. The ohmic resistance of field, brake, and clutch coils will be determined and the temperature at which obtained noted.

32. Spare parts ordered on requisitions for replacement of parts worn out in service may be shipped immediately without authorization, certified test reports and shipping memoranda being furnished as required, by paragraph 27, unless a

government inspector is present at the manufacturer's works, in which case inspection will be conducted in the usual manner.

33. A list of the contents of each box, properly marked for identification, will be secured to the inside of the cover and certified copies attached to the inspection reports. Boxes of spare parts will be properly sealed by inspectors.

TESTS AFTER INSTALLATION.

(See par. 97.)

34. Unless otherwise provided for, the ship contractor will be required to furnish the necessary apparatus, including recording instruments when considered necessary by the inspector, also labor to test the electrical auxiliaries under the supervision of a representative of the bureau in accordance with the requirements of the specifications, and conduct such necessary additional tests as may be prescribed by the inspector.

35. Similar tests will be made by the yard force, after installation, upon the electrical auxiliaries of vessels building or undergoing repairs at navy yards.

36. Complete reports of these tests will be made to the bureau in the manner prescribed by the specifications for finished plans and booklets.

GENERAL SPECIFICATIONS FOR ALL CONTROLLING APPLIANCES.

(Extracts from "General Specifications for Auxiliary Electric Appliances on Shipboard" of November 1, 1916.)

37. Controlling appliances will be designed for 230 volts direct current, unless otherwise specified, and will consist of apparatus for starting, stopping, reversing, and controlling the speed of motors, together with the necessary safety devices for the protection of the same.

38. Controllers will in general be of the "panel type," "drum type," or "contactor type," as specified for each auxiliary. When installed in wet spaces, or where powder either in tanks or bags is handled, they will be of inclosed watertight type.

39. Controlling appliances required to be of watertight type will permit of immersion without objectionable leakage. This test may be required by the bureau upon one or more controllers of a type to demonstrate this feature. The method of securing gaskets for watertight covers will conform to the requirements of paragraph 15.

40. Unless otherwise specified in the following detail specifications for each auxiliary, all auxiliary controlling appliances will be protected by suitable metallic casings, watertight or non-watertight as required, and with convenient access doors. Cover-securing bolts will be upset to prevent loss of wing nuts. The interior of these casings will be protected by waterproofed asbestos in the wake of arcing contacts or where liable to cause short circuits by contact with current-carrying parts. All nuts, bolts, pins, springs, and other small parts will be non-corrodible (composition, good sherardizing or heavy copper plating). Insulation will be non-absorbent and will be subjected to a high potential test as specified in paragraph 29(*g*).

41. Unless otherwise specified, panel-type controllers will be used for starting and regulating the speed of continuous running motors of 12 horsepower or less. For motors above 12 horsepower controllers will be of the drum or contactor type. In general, drum-type or contactor-type controllers will be used in connection with motors requiring frequent starting, stopping, and changing of speed.

41a. Large panels will be mounted on angle-iron supports and, if of slate, will be provided with one thickness of ⅛-inch rubber backing along vertical supports and two thicknesses along horizontal supports.

42. Small motors requiring less than 10 amperes current, which can be safely started by throwing directly on the line without previous acceleration, will be furnished only with a fused starting switch suitably inclosed.

Small contactor-type controllers conforming with all applicable requirements of these specifications, but with one accelerating contactor for motors of 3 kw. rated capacity and under and with two accelerating contactors for motors of over 3 kw. and less than 5 kw. rated capacity will be acceptable in lieu of panel-type controllers without speed control. These controllers will be fitted with main line fuses and will be designed for use with double-pole Navy standard line switches, which latter will be supplied by the government in the case of controllers purchased on requisition.

43. No controlling appliance will be installed until a sample equipment has been tested and approved by the bureau. Manufacturers desiring to submit their

apparatus for approval should communicate with the bureau concerned, when, if the type proposed appears suitable for the service for which intended, instructions will be issued providing for a test of a sample equipment at a navy yard. Plans will be furnished as required in paragraph 6.

44. Each controlling appliance must be accompanied by a diagram of electrical connections with each terminal designated to correspond to the marking of the appliance itself, which diagram will be pasted to the inside of the cover and protected by varnish.

45. All inclosed controlling appliances will be provided with suitable bosses or removable plates, which will be left blank, but will be suitable for the entrance of leaded and armored conductors in the manner specified in paragraph 14. Connections between controllers and rheostats where separately mounted will consist of Navy standard wire.

46. Controllers for reversible motors will have double-throw switches of double-throw starting arms. A double-pole, single-coil circuit breaker with separately closing sides each fitted with overload trips which disconnects the armature and field circuits from both sides of the line, will be considered equivalent to a fused line switch. When contactors and relays are arranged to afford the necessary protection, other no-voltage devices and overload circuit breakers will not be required.

PANEL-TYPE CONTROLLERS.

47. **Non-Watertight Panel.**—The panel will consist of an insulating base of approved material with durable smooth surface, upon the face of which are mounted a line switch, which opens both sides of the line, inclosed fuses, overload devices, no-voltage release, starting arm, field regulating arm (where required for adjustable speed), and the necessary contacts and terminals.

48. The panel will be supported on a rigid metal box frame, with solid top and bottom plates, and sides of perforated plates, which, with the solid back plate, will inclose and protect the resistances and connections behind the panel. Hinged metal doors with a composition lock and duplicate keys in accordance with the latest edition of Navy Department specifications applying thereto (uniform keys) will be provided unless otherwise specified for the protection of the face of the panel, and the frame will have feet attached, drilled for holding-down bolts not less than ½ inch in diameter. Sufficient space will be provided between the top and bottom plates and the terminals on the panel to permit the wires to be readily connected on the front of the panel. Terminal lugs of suitable size will be supplied with the panel.

49. The parts will be designed and arranged to conform to the following requirements:

(*a*) A sufficient number of field regulating points (14 points unless otherwise specified) will be provided to give a smooth and even speed regulation over the required range, and the lever will be held securely in any of these positions This lever will be so arranged that the motor cannot be started with weakened field.

(*b*) The starting arm will be so arranged that if it is left on any starting contact and the hand of the operator removed the circuit will be interrupted and the motor will stop.

(*c*) If the overload circuit breaker is of the type interconnected with and operated by the starting arm, it must be so arranged that it cannot be readily closed with the starting arm in any but the off position.

(*d*) The starting resistance must not be left in series with the shunt field in any running position.

(*e*) Provision will be made to prevent objectionable arcing at the first starting contact.

(*f*) Upon interrupting the circuit the shunt field will be so connected that inductive discharge will be absorbed by the armature, or else a separate field discharge resistance will be furnished.

(*g*) The field must not be energized with the starting arm in the off position.

(*h*) The no-voltage release must operate to cut off all current from the motor upon a 90 per cent reduction of voltage when magnetically operated and upon a 75 per cent reduction when manually operated. In both cases the magnet windings must not be connected in any motor circuit.

(*i*) The overload circuit breaker will be provided with efficient renewable arcing contacts, and must protect the motor and panel under any possible condition of overload. An overload device will not be accepted which short circuits the retaining magnet. The overload device will conform to all the applicable requirements for circuit breakers.

(*j*) All coils, except series coils, and current-carrying contacts which are subject to deterioration must be easily renewable from the face of the panel without disturbing the rear connections, and no part will extend beyond the edge of the panel. Field contact buttons need not be renewable.

50. **Watertight Panel.**—This panel will be inclosed in a rugged metal, watertight, flame-proof case, not less than $\frac{3}{32}$ inch thick, containing the necessary fittings, resistances, etc., to fulfill all the requirements for the "non-watertight" panel, contained in paragraphs 47-49 above, and with feet for attaching to the ship. The supporting bolts will in no case be less than ½ inch in diameter.

51. The case will be provided with suitable removable covers fitted with clamping devices of approved construction made watertight by means of rubber gaskets, which will permit easy access to the interior. It must be strong and substantial in design, but of lightest weight and smallest dimensions consistent with other requirements. The panel will be operated without opening the case, by means of levers or rods passing through composition stuffing tubes in the case, and the operating parts will be so designed as to reduce the number of these external handles to a minimum. Suitable marks and label plates will be placed on the case to indicate properly the position of the operating levers, and the external handles will be provided with indicating pointers, and will be detachable to prevent unauthorized manipulation.

DRUM-TYPE CONTROLLERS.

52. Drum-type controllers which fulfill all the requirements for panel-type controllers of both types enumerated above and in accordance with the following specifications will be accepted for the same purposes and will be installed in preference to the panel type for motors of 12 horsepower or less, where the service is very severe. (See par. 41.)

53. These controllers will be of the usual drum type with renewable copper or composition contacts attached to the operating cylinder rotating beneath copper or composition fingers, non-stubbing and readily removable, to which the circuits are connected.

All drum controllers must be inclosed, and when required to be waterproof will be provided with rugged metal housings not less than $\frac{3}{32}$ inch thick, and suitable rugged removable covers fitted with approved clamping devices and made waterproof by the use of rubber gaskets, at the same time allowing easy access to the interior. Supporting feet, provided with holes for holding-down bolts, not less than ½ inch in diameter, will be attached to the frame.

All operating levers will be easily rotated from any position, and the drum contacts will be maintained independent of the pressure on these levers.

Operating handles will be detachable and fitted with suitable pointers and the frame marked to designate clearly the proper operating positions and the "off" position. Means will be provided for retaining the handle securely at each position where necessary. In watertight controllers the handles and shafts will pass through composition stuffing boxes in the housing.

Controller fingers will be renewable, of rugged construction, capable of adjustment as to alignment and spring tension, and they must not be crippled by quickly turning the controller on or off.

The fingers and terminals for connecting up the leads will be easily accessible when the controller cover is removed.

All arc-rupturing contacts will be designed to withstand hard service for long periods, and controllers of over 30 amperes capacity will be provided with magnetic blowouts for suppressing the arc.

54. Drum controllers will be reversible or non-reversible for starting or regulating duty, or both, as specified in accordance with the character of motor to be controlled. Controllers will be so arranged that reversal cannot be effected without coming to the off position. Drum controllers for starting, or starting and field regulating duty, will conform to all applicable requirements for panel-type controllers and to the following:

(*a*) Where shunt-field control is required a sufficient number of field-regulating points (not less than 14 unless otherwise specified) in each direction of rotation will be provided to give a smooth and even speed variation over the required range. The lever will be automatically retained in any of these positions.

(*b*) The starting lever will be so arranged that if it is left on any starting position, and the hand of the operator removed, the circuit will be interrupted and the motor will stop; or, if desired, the starting resistance may be furnished of such capacity that it will carry continuously for 15 minutes the rated current of the motor without being seriously damaged, in which case the above-mentioned safety device may be omitted. Springs for accomplishing the return of the drum to the off position will be accepted only when specified.

(*c*) An overload device will be fitted which will protect the motor and controller under any condition of overload. This device will conform to all applicable requirements for circuit breakers, paragraphs 81-82.

If the overload device is of the type interconnected with and operated by the starting lever, it must be so arranged that it cannot be closed unless the starting resistance is all in circuit. Unless otherwise approved the overload device will be reset by returning the controller handle to the "off" position.

(*d*) The starting resistance must not be left in series with the shunt field in any running position.

(*e*) Upon interrupting the circuit the shunt field must be so connected that the inductive discharge will be absorbed by the armature, or else a separate discharge resistance will be furnished.

(*f*) A no-voltage release will be fitted which will cut off all current from the motor upon failure of voltage, and its winding must not be connected in any motor circuit.

SELF-CONTAINED DRUM CONTROLLERS.

55. When required for installation in connection with auxiliaries requiring frequent starting and stopping, or where compactness and few parts are desirable features, drum controllers of small capacity may be specified of the "self-contained" type, with the line switch, overload and no-voltage releases, resistances, and safety devices all mounted within the controller casing and controlled by external operating levers.

DRUM CONTROLLERS WITH PANELS.

56. When not required of the "self-contained" type, drum controllers will be furnished with a panel and the necessary rheostats, arranged for mounting separate from the drum. These panels will be inclosed in the same manner as "panel" type controllers.

CONTACTOR-TYPE CONTROLLERS.

57. In this type of controller the main motor circuits will be made and broken by solenoid switches or contactors controlled by a master switch or controller, and which can be located conveniently at any desired distance from the main controller.

58. The master controller will conform to all the applicable requirements for drum-type controllers when such a controller is necessary, otherwise master switches or push buttons will be furnished as specified for each auxiliary. In general master controllers will be used where speed control or stalled conditions are required; master switches will be used for starting and stopping reversible motors, and push-button control will be used for starting and stopping motors where distant control is required.

59. There will be mounted on the panels with the contactors, when required, the necessary current relays, interlocks, and auxiliary contacts, to insure the operation of the contactors in the proper sequence and at a current not exceeding a predetermined amount; also an overload trip coil with adjustable calibration which will interrupt the circuit of the holding coils of the contactors upon an overload, after which it will be necessary to return the master controller to the first or off position before the main controller can be again operated.

When operated in a normal manner it must not be possible to force the overload device and the contactors to operate alternately on an overload by leaving the master switch in a running position.

60. In the case of the no-voltage release for auxiliaries where no damage may result to apparatus or personnel the controller will be so arranged that the motor will automatically restart upon return of line voltage. Ordinarily it will be necessary to return the master controller or switch to the "off" position or again press the starting button.

61. Contactor-type controllers will be of the watertight or non-watertight type, as required, and will conform to all the applicable requirements of panel- and drum-type controllers. When required to be reversible, they will be so arranged that reversal can only be effected with the main contactors open, and they must be reversible from the point of distant control.

62. Dash pots or other means of mechanically controlling the speed of operation of automatic controllers will be accepted only when definitely approved.

63. Both sides of all pilot circuits will be protected with inclosed fuses. In the case of contactor panels for motors of 15 horsepower or over, means will be provided for testing the controller without starting the motor.

64. The shunt field must be disconnected from the line at the off position of the controller except in the case of machine-tool motors and where dynamic braking is required. Provision will be made for absorbing the inductive discharge either through the armature or by a separate resistance.

65. **Contactors.**—Contactors may be either shunt or series wound of approved type. They will function in a reliable manner when operated at maximum working temperature and 20 per cent below or 5 per cent above normal line voltage, and when subjected to destructive arcing will be provided with efficient renewable arc-rupturing contacts and magnetic blow-outs, to insure reliable operation under the most severe conditions.

66. They must not open or close by abnormal shock and must operate satisfactorily when inclined at an angle of 30° in any direction.

67. Coils which require renewal will be arranged for front connections. Except in the case of contactor panels for motors above 50 horsepower, terminal connections for external leads will be on the front of the panel.

68. Contactors will be adjustable throughout a wide range of current values and will be provided with pins, locking nuts, or other suitable means for resisting shock and vibration.

69. Contactors will operate at rated voltage and under normal operating conditions without exceeding the following temperature rises in the coils:

	°C.
Impregnated cotton or enamel insulation	65
Mica or asbestos insulation	75
Air insulated parts (except contacts)	40

70. All temperatures will be taken by thermometer, and no correction for room temperature (which latter will be taken by a thermometer placed approximately 18 inches below the controller) will be made. (See pars. 357-364.)

71. The total drop in voltage due to contact resistance and that of the main current carrying parts when operating at normal load will not exceed 3 per cent of the line voltage.

GENERAL SPECIFICATIONS FOR ALL RHEOSTATS.

72. **Resistances.**—The material of the resistance will be non-combustible at operating temperatures, non-corrodible, and not damageable by shock, by salt air, or salt water, or by heating to a low red heat. Insulating material will be non-absorbent.

73. Cast grid resistance may be used where absolute resistance values are not essential, except that in turrets or in locations exposed to the shock of gunfire no form of cast grid will be accepted unless the same has been thoroughly tested to stand severe shock. The grids will be thoroughly protected against corrosion in such a manner as not to give off objectionable smoke, and securely fastened in the supporting frame at a sufficient number of points to prevent damage from shocks, and the method of mounting will permit of ready connection of the leads and removal of the grids for repairs.

74. In cases where absolute resistance values are essential, such as field rheostats, etc., the resistance material shall not appreciably change its resistance with

rise of temperature or with age. Field rheostats and other similar continuous-duty resistances must carry rated current continuously without exceeding a temperature rise of 175° C.

75. Continuous-duty resistances where constant resistance values are not essential, such as that for field discharge, contactor protective resistance, etc., must carry rated current without exceeding a temperature rise of 200° C.

76. Resistances for intermittent or starting duty must be capable of carrying 50 per cent overload current for one minute and 100 per cent overload current for 20 seconds without damage, each test starting cold. This test will be applied to one controller of each lot and size.

77. All temperatures will be taken in the manner specified in paragraph 70. The insulation will be subjected to a high potential test as specified in paragraph 93(*a*).

78. **Resistances for Mounting in the Case of Controllers.**—These resistances will be of the unit type, so constructed and installed that each unit may be replaced. The method of mounting and insulating the resistance will be such that fused metal will not drop out of the case. No resistance will be used until a sample has been approved by the bureau. All connecting wires must be capable of carrying full current under normal operating conditions without becoming dangerously hot.

79. **Resistances for Separate Mounting.**—These resistances will be supported in rugged metal frames, with feet attached for bolting to the ship, and will be suitably inclosed after installation by a wire-mesh screen. Unless a special location is provided with sufficient protection against moisture and danger from a burnout, the resistance will be so encased and mounted that it will be protected against dropping water and that fused metal will be prevented from dropping out of the case by a solid bottom flanged upon all sides. In locations exposed to the weather, or where powder either in bags or tanks is handled, these resistances must be completely inclosed in rugged watertight metal cases, not less than $\frac{3}{32}$ inch thick, with removable covers, and the entering leads will be made watertight with the case. Provision will be made for readily connecting the leads to the resistance steps and for preventing contact with the heated resistance material. Rheostats must conform to the additional requirements under the detail specifications for each auxiliary.

80. **Discharge Resistances.**—Suitable discharge resistances will be provided for the shunt fields of motors, and, unless waived by the bureau, for the coils of iron-clad brakes, clutches, etc., unless other measures are taken to absorb the inductive discharge of these coils when the circuit is interrupted.

These resistances will conform to the foregoing requirements for the same, and will be mounted within the controller casing or in any other suitable protected location. They must be so arranged that it will be impossible to leave them connected directly across the line unless they are designed for continuous duty at full voltage.

GENERAL SPECIFICATIONS FOR CIRCUIT BREAKERS FOR AUXILIARY CONTROL APPLIANCES.

81. Circuit breakers must be able easily to open a circuit carrying their maximum rated current at a potential of 250 volts without holding an arc at any place or injuring the main contacts, and must open the circuit on short circuit without serious damage to the breaker. They will be adjustable within their capacity and provided with a graduated scale to permit of adjustment to 100 per cent overload.

The maximum rated current of the apparatus protected must be carried under actual operating conditions without the temperature rise in any part exceeding 40° C., measured by thermometer (except current-carrying coils, which must not exceed 50° C. by thermometer). The arc-rupturing and the main contacts will be simple in construction and easily renewable when worn out, and must have a rubbing or sliding effect, tending to keep the contacts clean. Double pole breakers must have independently operating arms, or be of the type which cannot be held closed on an overload. Circuit breakers must conform to requirements prescribed by the latest rules of the National Board of Fire Underwriters. The tripping device will be capable of withstanding severe shock without opening, and in the case of circuit breakers for installation in turrets or where exposed to the shock of gunfire, specific tests will be applied to determine the ability of the breakers to withstand this service. They must operate satisfactorily when inclined at an angle of 30° in any direction.

82. Circuit breakers exposed to the weather or to inflammable gases, and in locations where powder in bags or tanks is handled—when not mounted in watertight controller cases—must be inclosed in individual metal watertight boxes not less than $\frac{3}{32}$ inch thick with removable covers made watertight by the use of rubber gaskets and provided with clamping devices of approved construction. The setting and tripping handles will operate from the outside through composition stuffing boxes.

When not required to be watertight, circuit breakers will be protected in a manner similar to non-watertight panel type controllers.

FUSES AND SWITCHES.

83. Fuses will be of the inclosed type or inclosed renewable type and will conform to the latest edition of Navy Department specifications applying thereto. Fuses will be supplied having a rating 50 per cent in excess of the full-load current of the apparatus protected. Renewable links will be considered as spares in the case of renewable fuses, except that one complete spare fuse will be furnished for each panel. Switches will conform to the requirements for the same contained in the latest edition of the National Electrical Code issued by the National Board of Fire Underwriters, except as relates to the spacing of switch blades, which is subject to the bureau's approval. Fuses and switches will be mounted and protected in accordance with the requirements of panel type controllers.

MAGNET COILS.

84. All windings of magnet coils not provided with water or fireproof insulation used in connection with controlling appliances will be made waterproof by vacuum impregnation or by other approved method. All coils will be protected from mechanical injury. Renewable coils will be front connected on the panel, and will not exceed the temperatures specified in paragraph 69.

SPRINGS AND CONTACTS.

85. All springs will be strong enough to insure the proper functioning of the apparatus to which attached. Springs will not be depended upon to carry current. Where required, springs will be adjustable for tension.

86. All contacts will be of simple and rugged construction. Armature current-carrying contacts will be easily renewable without taking down the apparatus.

Sliding brushes will be easily renewable and so designed as not to be blocked by slight projections on the contacts. Provision will be made for protecting the contacts from damage by arcing.

TERMINALS AND CONNECTIONS.

87. Terminals will be arranged for front connection in the case of panels for motors of 50 horsepower and less and will be sufficiently heavy to support the connections in a reliable manner and prevent heating under normal operating conditions. They will in all cases be permanently marked with designating letters, corresponding with the marking on the diagram of connections, which will be generally as follows: Line "L_1," "L_2"; armature "A_1," "A_2"; field "F_1," "F_2"; brake "B_1," "B_2"; clutch "C_1," "C_2"; rheostat "R_1," "R_2," "R_3," etc., and such combinations of these letters as may be necessary, as "AF," "AB," etc. It is preferred that line terminals be at the top of panels and all others at the bottom. Terminals carrying 25 amperes or more will be provided with suitable lugs into which the wires will be soldered, except in the case of leads to fingers of drum controllers or rheostat leads exposed to high temperatures.

88. Permanent connecting wires for controlling appliances will be of sufficient capacity for continuous service duty and will be well insulated to prevent grounding through chafing of the wires, and where exposed to the heat of rheostats will be insulated with an approved fireproof insulation. No wires smaller than 4000 C. M. will be used. No solid wire less than 10,000 C. M. will be used for the connections of controlling appliances. All connections will be provided with efficient locking devices to prevent their becoming loosened by shock or vibration.

INSULATION.

89. The electric circuits of all controlling appliances will be thoroughly insulated from the metallic supporting frame. The insulating material will be non-combustible, non-absorbent, and not damageable by heating to a temperature of 125° C. When such insulating material is exposed to the heat of rheostats, or to arcing, it shall be capable of withstanding the severe heating without deterioration or smoking.

MATERIAL, WEIGHT, AND FINISH.

90. All operating parts of controlling appliances will be strong and substantial. Where the employment of oxidable metal is necessary for magnetic purposes, the contact surfaces shall be protected against oxidation by copper plating or other approved coating and other surfaces by a heavy coating of black enamel. Frames and casings will be protected by a heavy coating of black japan. Apparatus will be as compact and light as possible consistent with other requirements.

NAME PLATE.

91. A name plate bearing the following data will be attached to all controlling appliances: Name of manufacturer, purpose, manufacturer's type, and shop number, volts, amperes, bureau, space for stamping name of ship, and initials or stamp of inspector, and year of manufacture.

TEST OF CONTROLLING APPLIANCES.

92. Controlling appliances will be subjected to the same tests (except overload tests) as the motors which they control, and when tested in connection with the completed auxiliaries on shipboard, they must afford satisfactory control without damage to themselves or the motors, or weakness, or overheating in any point.

93. Each controlling appliance, in addition to a surface inspection to determine compliance with the foregoing specifications and with the approved plans and specifications, will be subjected to the following tests:

(*a*) A high potential test in which 1500 volts A. C. supplied from a generator or transformer of at least 2 kw. capacity will be applied for a period of one minute.

(*b*) A determination of the resistance values for each step of armature and field resistance, also all other resistances and each shunt winding. (Par. 74.)

One controlling appliance of each lot and type will be given the following tests:

(*c*) Operation with a suitable motor.
(*d*) Heating. (See pars. 69, 74, 75, 76, 77, 81, 84, and 89.)
(*e*) Operation at reduced voltage. (See par. 65.)
(*f*) Shock and inclination. (See pars. 66 and 81.)
(*g*) Watertight test. (As required. See par. 39.)
(*h*) Adjustment. (See pars. 68 and 81.)

One controller of each size and kind shall be tested for voltage drop (see par. 71). This test need not be repeated on subsequent orders unless design is changed.

94. Test reports will be submitted in accordance with standard blank forms, copies of which may be obtained upon application. The manner in which inspection is to be conducted will be similar to that covered in paragraphs 27 and 32.

CONTROLLER SPARE PARTS.

95. Spare parts for controlling appliances will be furnished in accordance with paragraphs 31, 32, 33, 338, 339, and 341.

Inspection of spare parts will cover those tests contained in paragraphs 93(*a*) and (*b*).

GENERAL REQUIREMENTS FOR ALL AUXILIARIES.

(Extracts from "General Specifications for Auxiliary Electric Appliances on Shipboard" of November 1, 1916.)

96. All auxiliaries and their electrical equipment will conform to the foregoing, the requirements of the "General Specifications," the "Detail Specifications," and to the requirements contained herein.

97. In addition to the shop tests required under the foregoing specifications (pars. 27, 29, 30, 92, 93, and 94) for motors and controlling appliances as amplified for each auxiliary, all electric auxiliaries for contract ships building will be given the specified ship tests after installation under the supervision of the bureau's representative and at the contractor's expense (pars. 34-36). The data will be taken in accordance with and recorded on standard test report forms which will be accompanied by suitable performance curves where practicable. Copies of these forms may be had upon application to the bureau concerned. (See pars. 34-36.)

98. Insulation tests at operating temperatures after installation and within two weeks of the date of delivery of the vessel will be made (using the highest direct-current voltage available) on all circuits of each electric auxiliary. Under these conditions the insulation resistance of the complete equipment must not be less than one-third megohm.

99. Except in the case of steering gears and windlasses all motor pinions will be of rawhide, cloth, or fiber.

Where worm gears are used means will be provided for taking up the thrust outside of the motor.

All gearing will be inclosed and suitably lubricated. All necessary safety appliances should be provided. Everything else being equal preference will be given to the machine which best safeguards the operator from injury.

100. All electric auxiliaries furnished by the government shall be tested by the ship contractors after installation, to obtain the performance data required for the Booklet of Tests. (See Appendix 16 to the General Specifications issued by the Navy Dept., Bu. C. & R.)

101. Cast iron will not be used for bedplates or other large castings except by specific authority from the bureau. Large bedplates will be split in a suitable manner when required to facilitate handling.

101a. When specially approved, large size controlling panels need not be fitted with inclosing cases, provided they are adequately protected, by wire mesh or other approved means, against unauthorized manipulation.

Note.—Paragraphs 338-356 inclusive refer to lists of spare parts and method of boxing and stowing and are not quoted.

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